Technical guide for master trainers: Earthquake resistant buildings using local materials in Dolakha, Ramechhap and Sindhuli - Nepal

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Other sources :
Nepalese Building Code (NBC)
NRCS Mason training presentation

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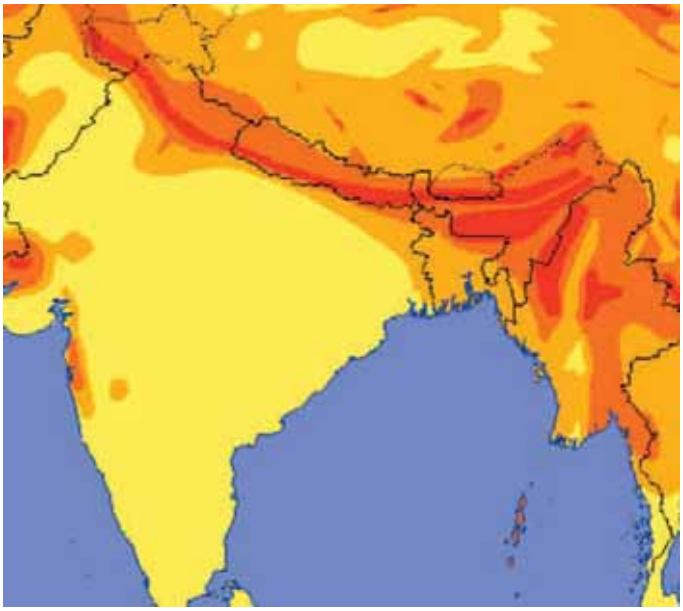
SUMMARY

This guide is primarily aimed to be used in the reconstruction projects for the villages in the districts of Dolakha, Ramechhap and Sindhuli - Nepal.



The reader should know that:

The general methodological approach of this guide can be adapted to other regions.

Nevertheless, some of the technical proposals are specifically fitted to the cultural, economical and social contexts of Dolakha, Ramechhap and/or Sindhuli, and may not be directly usable in other regions. For those purposes, a thorough analysis should be conducted, in order to define a guide adjusted to that specific context.

The technical proposals included in this guide are presented as valid options, resulting from a thorough context analysis, but they do not stand as the only valid ones, nor do they pretend to, as other choices can also present technically fit sollutions and pertinence for the overall approach.

The *session duration* indicated for each *Lesson Plan* is a mere recommendation and should be adjusted to the real context and existing circumstances by the training team.

WHAT YOU WILL FIND IN THIS GUIDE :

Technical solutions that can be applied in the geographical, social, economic context of Dolakha, Ramechhap and Sindhuli districts. They can be applied to the following materials: stone, earth, bamboo and wood.

WHAT YOU WILL NOT FIND IN THIS GUIDE :

Solutions that can be applied to any context and/or any constructive system.
(any use of this guide outside from the context it has been designed for should be preceeded by a proper analysis and a thorough technical and contextual adjustement)

LESSON PLAN

INTRODUCTION

Origin of earthquakes

0-2

Session duration: 1 hour

Objectives:
Make participant conscious that earthquake are recurrent and intensity may vary
Help Trainees to develop an earthquake prone area behaviour (identify indicator, plan of rescue, etc.) and conscientize them about the necessity to advocate for the development of such behaviour.

Method:
Help trainees to understand the tectonics plate movements. Trainees will share their knowledge about earthquake, the trainers will synthetise and complete after trainees restitutions. He will illustrate the plate movement and their consequences.
Ask trainees to talk about their previous experience when they faced the earthquake, and to develop a security plan based on the lessons learnt.

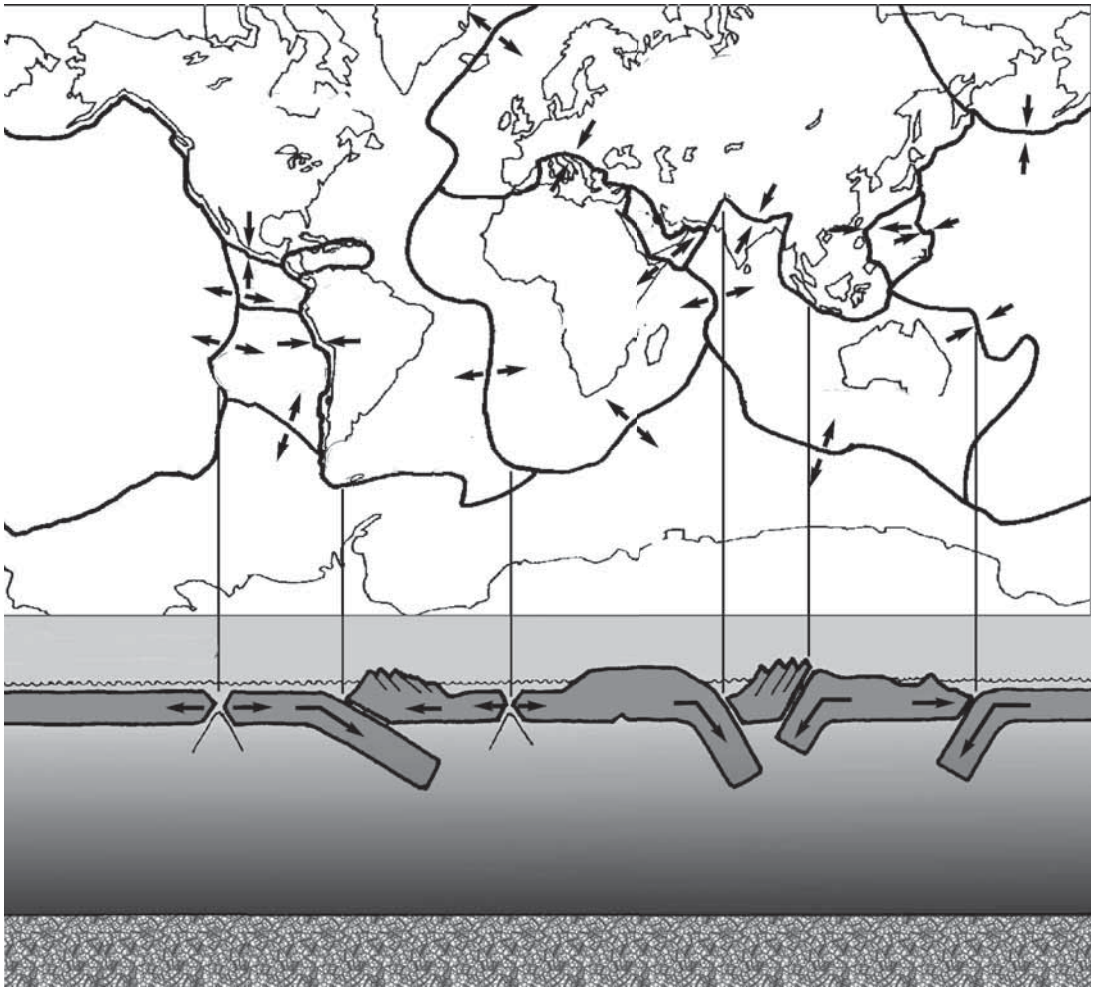
Trainer team	Session	Pedagogical support :	Tools :
Lecture One trainer for 20 participant	Preparatory work : Organise a board where can be fixed the pedagogical material (plasticized paper) Organise the room or open site in order to help trainees to have free access to all the documentation fixed on the boards Organise chairs, booknote and pen for participant Translate necessary material in local language. Lecture: Introduction about the topic of the session The trainer will explain the necessity to understand a phenomenon before to try to develop adequate answer to face its potential effect. Trainees will be required to organise themselves in group of 4 to 6 persons in order to answer the following questions (the trainers may add other questions, adapt or complete these questions, this in order to its own sensibility). 20 mn will be given to the trainees to answer the questions. Then they will be required to restitute their discussion to the others. What do the trainees know about earthquake? (objective: to help trainees to share their knowledge and discuss this issue) Do they know how it happens? (objective: to help trainees to understand the recurance of such events) Do they remember precedent earthquake; does their ancestor was use to talk about earthquake? (objectives: To help to know about the periodicity of earthquake in the particular region. For the trainer, it may help to understand if there is chance or not for a surviving local sismic culture). Do those 2 recent earthquakes can be considered as a big ones or as normal ones in the region? (objectives: This question aim to give back confidence to the trainees in order to think on reconstruction. Even if there is no certitude, they may realise that the present earthquake was particulary big and that there is some chance for it to not happen again similarly in the next decades). Describe what were the different step of the earthquake? (sound, ground movement, animal behaviour; let the trainees relate the different things they notice). During the restitution, the trainer will help various trainees to interact on the subject and develop a common perception of the phenomenom. Then, he will synthesise and if necessary complete the information given by the trainees. It is recommended to use the trainees arguments or expalnation to develop this synthesis. Then, He will ask the trainees to develop a emergency policy related to their own families, or village. The trainer should be mind open and note interesting comments given by the trainees as it can give relevant information about the seismic activity in the area and about people perception of this phenomenon.	Demonstration: Possibility to use two stone to represent the tectonic plate. Illustrate the various interaction between the plate. Explain reason of earthquake intensity.	Two flat stone.

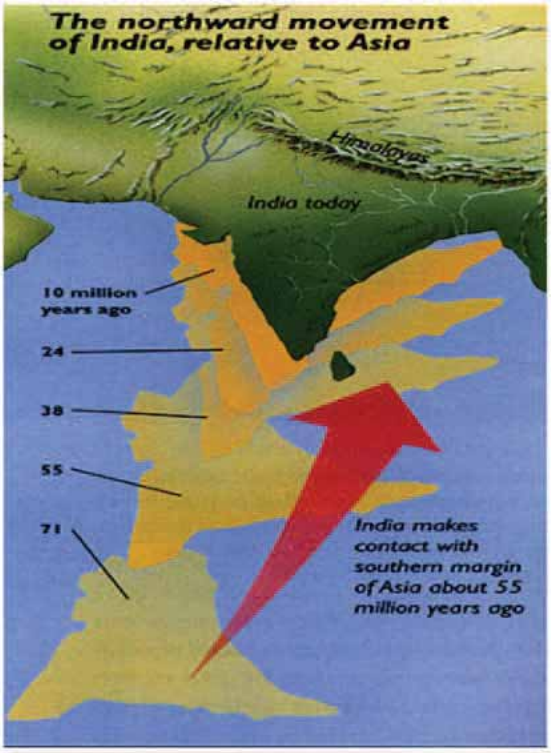
Planning

Before the session: Identify site for the session, taking care of potential risk related to weather conditions
Take into account the method of working into group while selecting the site (need for group to isolate themselves during group work)
Be sure of language to be used during the training.

Lecture Take care to help all trainees to participate in the discussion. Leaders, or trainees who attented other related training may take the lead for all the group and reduce the interest of the participatory approach.

After lecture Adjust the lecture plan as well as the pedagogical support if necessary.





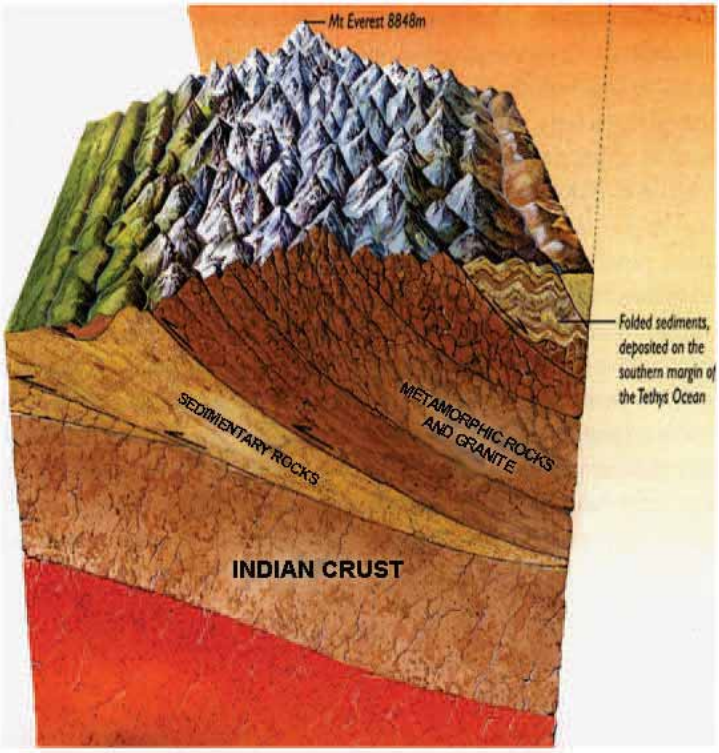


Illustration from NRCS mason training presentation

Illustrations from NRCS mason training presentation

LESSON PLAN

INTRODUCTION

Earthquake's effects

0-5

Session duration: 10mn

Objectives :
Help trainees to understand how a construction behaves when facing an earthquake.

Aim:
Help trainees to take into account the seismic effect when they will design and construct a building.

Method : Interaction with the trainees
- Help trainees to understand the various constraints given to a building by a seism
- Help trainees to understand the movement generated.
- Help trainees to understand possible effect on the building and its surrounding

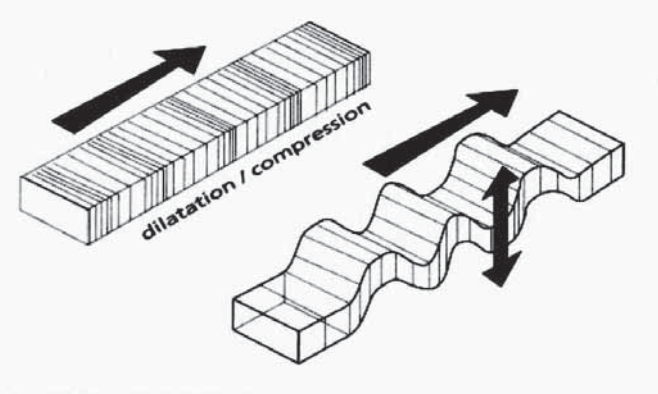
Trainer team	Session	Pedagogical support :	Tools :
Lecture One trainer for 20 trainees.	Lecture: After a short recap on the Earthquake actions ask the trainees on how the soil may react to this phenomenon (what could be the different movement created). Ø Illustrate the different waves and explain them shortly o Compression o Vertical movement o Horizontal movement o Elliptic movement Ø Dynamic effect o Acceleration o Speed o Displacement o Frequency and intensity related to nature of the soil Then, ask the trainees on how these different phenomenons interact with the building. Ø Main action on the building o Vertical § Loose of mass o Horizontal o Torsion Then, ask the trainees on what could be the consequence of these actions to the building and its surrounding. Ø Main effect on buildings and its surrounding o Effect on the site (landslides, rolling rocks, etc) o Ground distortion o Separation of element o Shearing of the element	Demonstration: One flexible wooden or plastic stick.  Trainees guide: Copy of the flyers	

Planning

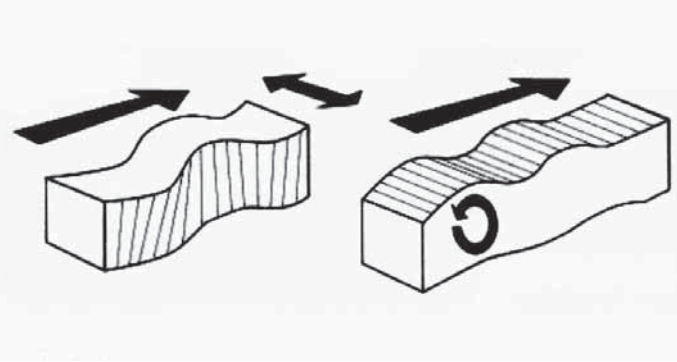
before session Identify in the area existing example of the issue the trainers want to demonstrate. A compilation of picture may be addeb to the existing files containt into this trainer guide.

Lecture Note all remarks and inputs from the trainees.

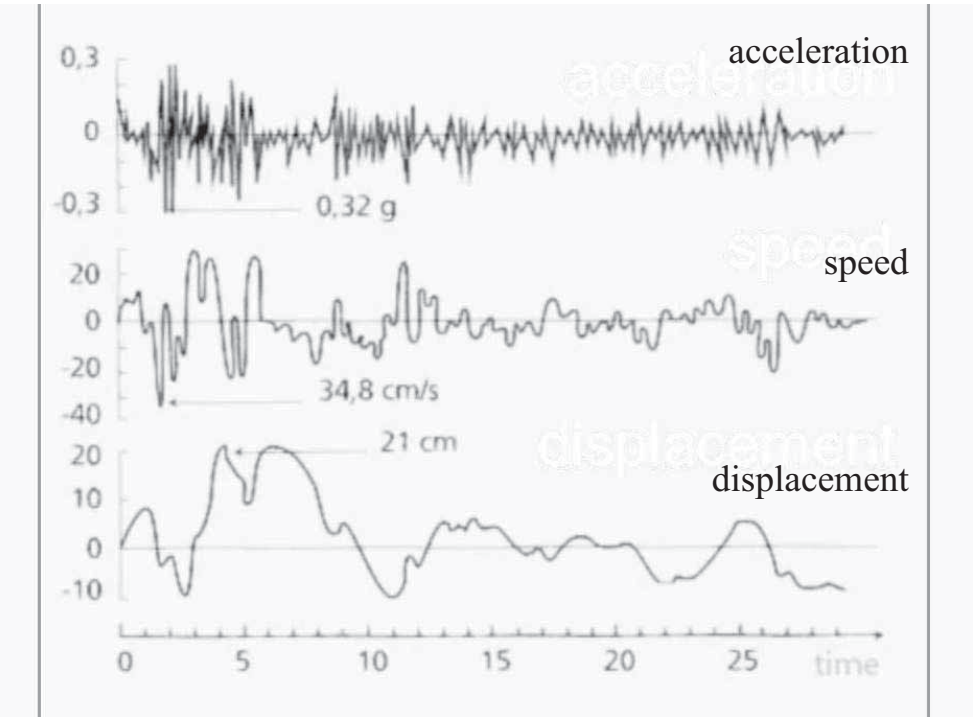
After lecture Improve on the lecture contain, add relevant material according to trainees response to the one presented.



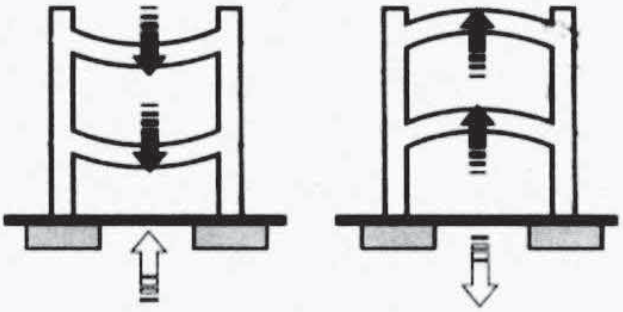
VOLUME WAVES



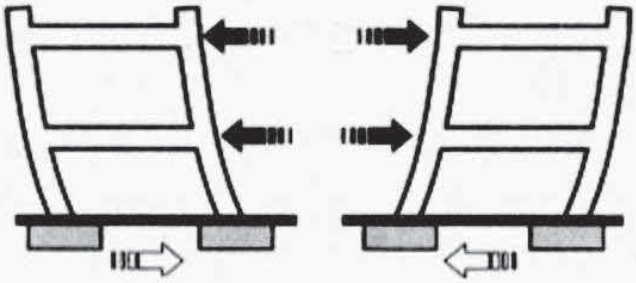
SURFACE WAVES



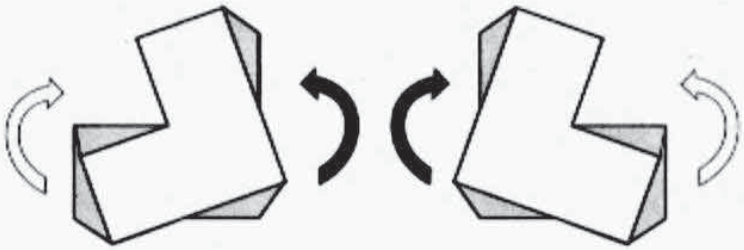
A DYNAMIC LASTING PHENOMENON



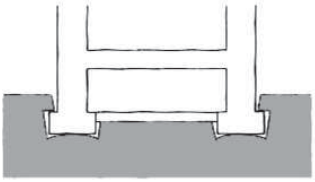
vertical oscillations



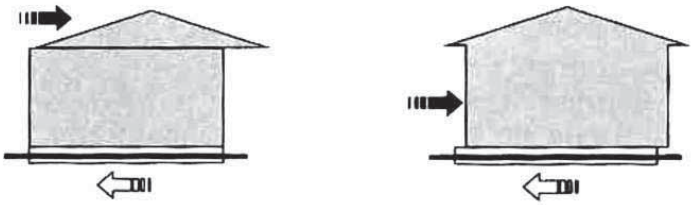
horizontal oscillations



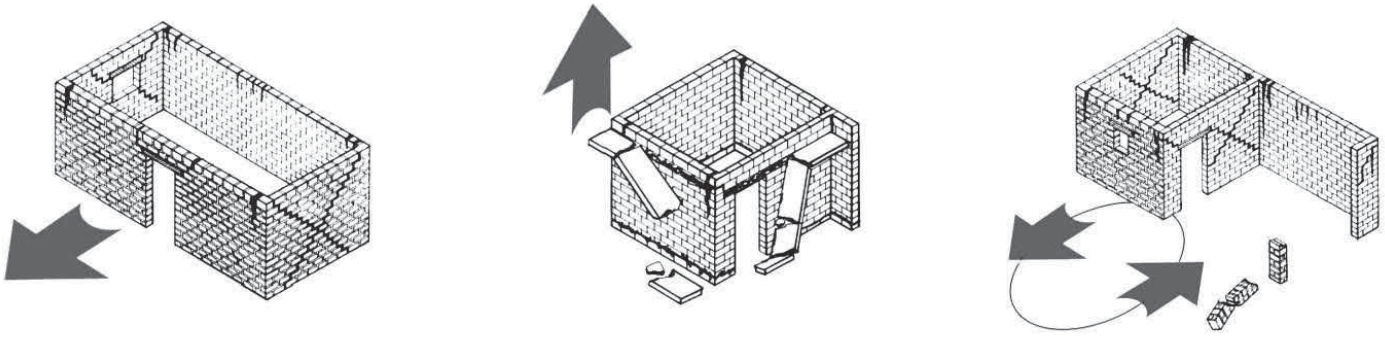
torsion oscillations



ground distorsion



separation of the elements



shearing of the elements

LESSON PLAN

INTRODUCTION
Earthquake resistant (EQR) building design

0-9

Session duration: 10mn

Objectives: Understand the different factors that are interfering in the seismic resistance of a building.

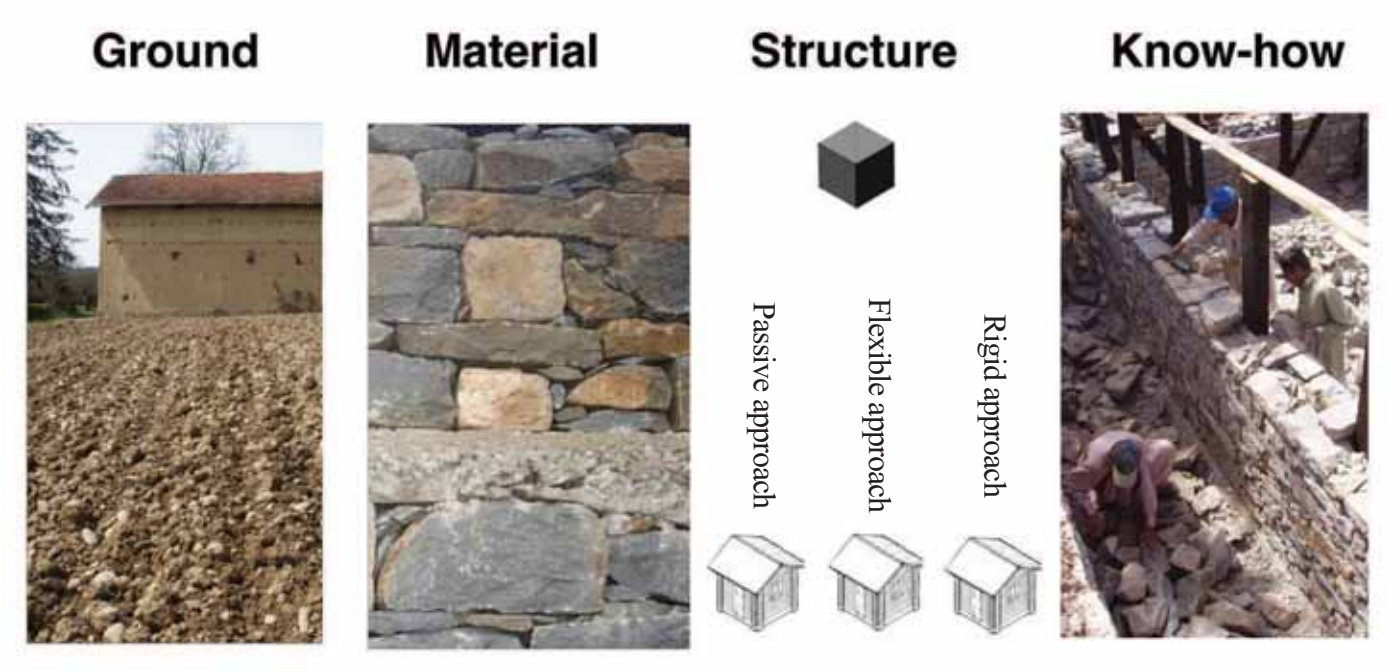
Aim:
Sensitize trainees to the fact that there are numerous factors to take into account to achieve seismic resistant building. There is not a unique solution.

Method : participatory discussions

Trainer team	Preparatory work :	Pedagogical support :	Tools :
Lecture: One trainer for 20 trainees.	Lecture: To understand ground effect and interactions with the building; The resonance factors Ø Demonstration with the wire and mass on the plank. Ø Analysis by the trainees (open discussion) Ø Conclusion; importance of the design and the structural choice in relation with the type of ground where the building will be implemented Ø Ask trainees to relate the topic to some existing and real case (high mountain versus valley) Nature of material and their specific quality and weaknesses. Ø Compression Ø Traction Ø Ductility Ø Mode of rupture Various structure Ø Passive Ø The choice of absorption Ø The choice of resistance Quality of workmanship. Ø Quality / Skills / Training Ø Quality control Ø Capacity or not of technical choice to accept poor workmanship.	Demonstration: Model to illustrate the movement of a building according to its frequency (wire loaded on a plank) Trainer guide:	

Planning
Before session
Lecture
After lecture .

Earthquake resistance depends directly on the four following factors:



The aim of building design in earthquake prone areas is to save human lives.

Three main different approaches on earthquake resistant design have been adopted along history:

the *rigid* approach : building ever more rigid structures, capable of withstanding horizontal and torsional forces;

the *flexible* approach : protecting a building against the effects of earthquakes by allowing its structure to deform and dissipate energy;

the *passive* approach : allowing the building to collapse, but with minimum problems for the occupants, and making the building's reconstruction as easy and fast as possible.

This guide is providing design and building technics aiming to achieve buildings that will preserve as many lives as possible, leaving maximum time for the people inside to come out before an eventual collapse.

In this approach, which could also be named the "elastic domain approach", the way to ensure the resistance of the building is by increasing the resistance of the elements. The structure is designed to resist and stay in its elastic phase.

The energy is stocked and given back during the oscillations. The only way for it to dissipate energy is through internal damping of the structural elements, and ultimatelly through breakage of the elements - which could lead to the destruction of the building.

One of the important aspects on this type of design is the need for an homogeneous rigidity of the structure. This is generally assessed through maximum rigidity of every element and of every link between the different elements.

This is the most common "engineered" way of designing buildings. One of its advantages is that the behavior of building materials in the elastic domain is easily predictable and models are accurate. It is therefore suitable for calculation, codes and regulations.

On the other hand, the know-how and materials required to obtain quality levels that ensure the seismic resistance are of high standards and may not be available in every context.

In this approach, the main source of protection is the dissipation of energy, mainly through post-elastic or plastic response of structural elements.

The "modern engineering" way of doing this is by using damping apparatus (through plastic deformation or friction), breakable fuses or designing structure with high degree of hyperstatism with plastic nodes.

The vernacular way that we can find in many seismic cultures around the world is not so different in theory, but using mainly:

- the friction between elements: For example friction between wooden structure and stone masonry, and/or between the parts of the wooden structure.
- the post-elastic behavior of masonry structure: For example, fissuring and breakage of elements and friction at the interfaces between broken parts or between stones in dry masonry. The 12 year research program of the Getty Institute shows the importance of this phenomenon for earthquake resistance of adobe walls.

In this approach, it is therefore important to keep the ability of the structure to deform, though ensuring their stability even after breakage or deformation of the elements.

This type of phenomenon is very difficult to model and predict, as every structure has a different behavior. It is therefore difficult to use as a standard. But the observation shows a lot of local seismic cultures using this type of structure with good results.

The reader could learn more about this in:

Getty seismic adobe project, report of third year activities. Shaking table tests of large scale adobe structures / W.S. Ginell, E.L. Tolles, P. Gavrilovic, L. Krestevska, V. Sendova, L. Taskov / Los Angeles: GCI, 2001

L*ocal seismic cultures and earthquake vulnerability reduction in traditional masonry buildings* / Proceedings of the 12th intensive course of the European university centre for cultural heritage, Ravello, Italy, December 11-17 2002

LESSON PLAN	INTRODUCTION Local seismic cultures (LSC)	0-13

Session duration: 20mn

Objectives: Enlighten the capacities of local engineering to develop adequate answer to their own needs. Help people to believe on their potential; to be proud of their own culture. Make people open to understand the existing and learn from it.

Method: Help people to rediscover their own local seismic culture

Trainer team	Session	Pedagogical support :	Tools :
Lecture One trainer for 20 trainees.	Preparatory work : Ø Identified the existing LSC in the area Ø Document it Ø Find similar example existing in other part of the world Lecture: Ø Definition Ø Conditions required for their development Ø Ask the trainees to identified the LSC they know; how do they learn from it. Ø Synthesis of the existing LSC o Principle of LSC in Dolakha, Ramechhap & Sindhuli districts. Ø Potential interest in the reconstruction programme o Existing local culture o Existing knowledge o Existing material Ø Risk and limitation o Availability of material (sustainability) o Acceptability by the inhabitant o People expectation Note: At the end of this lecture, it is very scarce to have a lot of identified LSC. But this lecture open people mind and feed back from the trainees come latter during the following sessions.	Demonstration: Trainer guide:	

Planning
Before session
Lecture
After lecture

“Before the modern movement toward systematization started, the only way in which a local community could protect itself from natural disasters was to draw on its experience and, in particular, to build upon previous failures. Ineffectual techniques were abandoned, while those which proved to be effective were handed down from generation to generation and were further improved following each earthquake.

No wonder, therefore, that in earthquake prone regions all over the world (and only there) the techniques adopted to build monuments were extremely sophisticated and provided effective protection against horizontal stress.

No wonder, also, that the rules governing anti-seismic building in earthquake regions everywhere are fairly similar despite the use of different materials and different local techniques.

No wonder, lastly, that these areas, especially poorer ones, continue to employ techniques used in villages nearly 4,500 years ago.

Ancient buildings have been able to withstand earthquakes thanks to specific anti-seismic techniques used to construct them. A rich body of literature even provides evidence that traditional anti-seismic techniques dating back thousands of years (Shiping Hu, 1991; Touliatos, 1992) have survived to this day with few changes and have generated widespread standard practices and mechanical models clearly recognizable today (Giuffrè, 1993). There is enough evidence to conclude that real Local Seismic Cultures are firmly established in earthquake regions with technical, cultural as well as social and economic implications making them extremely current.”

Ferruccio Ferrigni in ANCIENT BUILDINGS AND EARTHQUAKES Reducing the vulnerability of historical built-up environment by recovering the Local Seismic Culture: principles, methods, potentialities , 2005 - Edipuglia , pp.298 and 299

The modernist approach has always had the tendency to make us believe that the human being can free himself of his natural environment and the formal education system has often blindly promoted foreign models in a very detrimental way to the local ones. It has also extracted from communities their best individuals, those who would probably have been the ones who could have invented new solutions, adapted to the new situation. In these conditions, traditional models have often been depreciated and the know-how attached to it partly lost. New initiatives, even if ingenious, remain often poorly adapted, from the social, technical, cultural or environmental points of view. This evolution is peculiarly clear when looking at the evolution of human settlements and architectural models.

This technical guide is an initiative to respond to these problems. The hypothesis is that traditional architecture can be a basis on which one can develop a new local architecture that addresses contemporary expectations and needs of the population but also better respects the realities of the environment and therefore contributes to the establishment of a sustainable development process".

The proposed iterative method is based on the successive implementation of the following four activities.

· Study and analyze of the building sector and its environment

· Design of relevant action and strategies to be implemented

· Implementation of activities

· Evaluation and analyze of results obtained to be able to design following activities

This cycle is repeated as often as it is necessary to allow a permanent improvement of technical proposal given to beneficiaries as well as to permit projects partners to build their own competencies progressively up to handle all projects activities on their own.

LESSON PLAN

GENERALS

Site Selection

1-1

Session duration: 20mn

Objectives: To help the trainees to take into account the risk linked to the site

Method: Observation, Historical background.

Trainer team	Preparatory work :	Pedagogical support :	Tools :
Lecture One trainer for 20 trainees.	Identify evidence of site effect in the concerned area. If not, develop a database including pictures of the various site effect described durring the lecture. Print these picture in A4 format. Expose the pictures in the classroom as the trainees could have free access to these pictures. Lecture: Ask the trainees to describe potential effect of an earthquake on the site stability. Complete with exhaustive list of potential effects Indicator of historical ground movement Indicator of recent movement Indicator of potential future movement Synthezise the information given by trainees. If possible organise a site visit or a case study to help the trainees to acquire physical experience of identification of potential risk.	Demonstration: Use picture of in situ situation Trainer guide:	

Planning
Before session
Lecture
After lecture

Proper selection of the building site before construction is of major importance.

General considerations

The land should be preferably high and with a slight slope, to prevent from the risks of stagnant water and of rain water over-flow.

Made-up-grounds, water lodged areas are unsuitable for buildings. Greater care must be taken when dealing with such ground or soils.

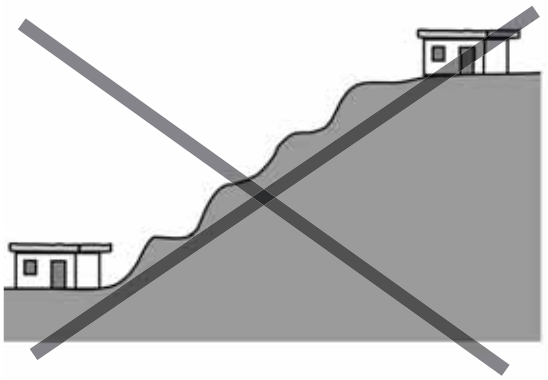
Avoid constructing on a site with too many trees, where roots could affect the construction. It is advised not to construct less than 15 feet away from a tree.

Seismic considerations

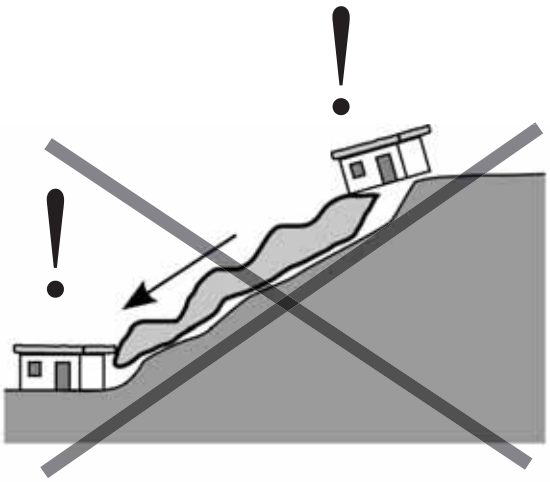
The land should not present signs of landslide possibilities, particularly for terrace building sites.

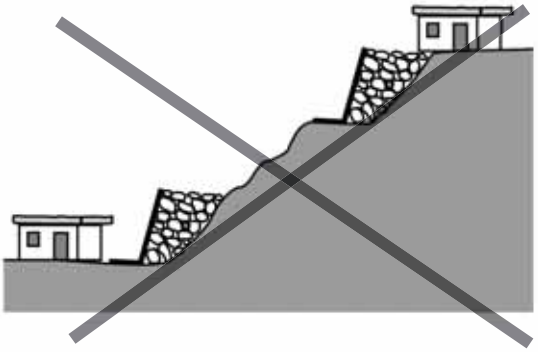
Avoid the following lands:

- under or on top of cliffs presenting cracks;
- close to retaining walls, specially when affected by previous earthquakes;
- on slopes with old landslides, that can be revealed by the wave form of the soil;
- on lands near inclined trees or electric poles.

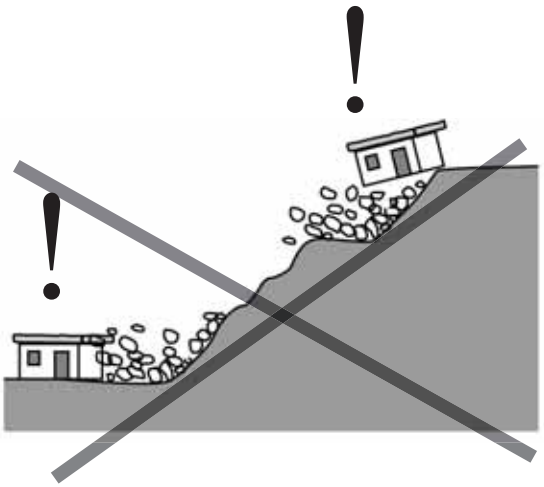


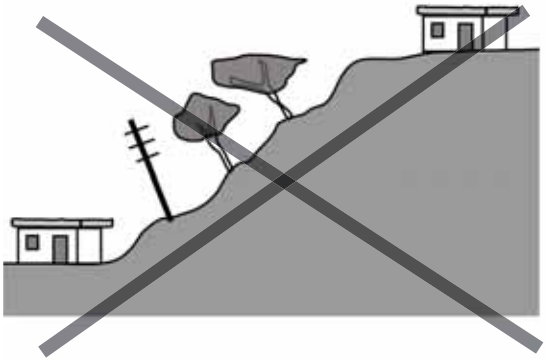
LANDSLIDE

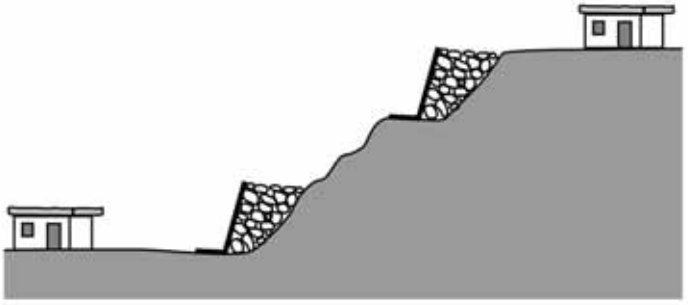




TERRACE FAILURE



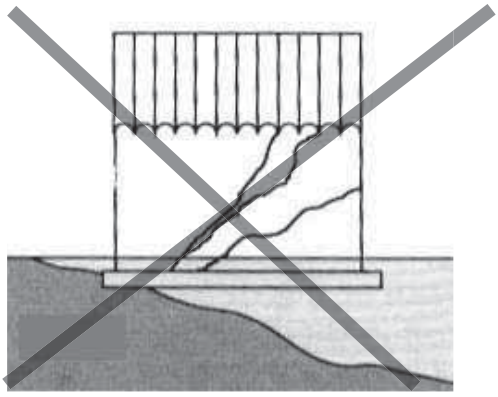


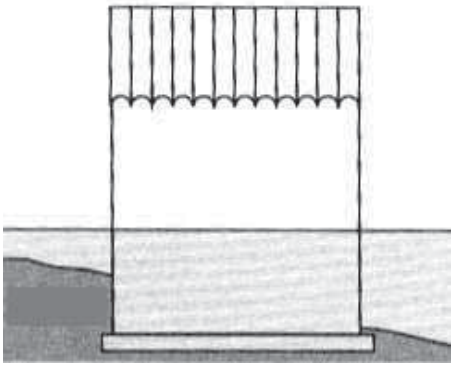


GOOD LOCATION

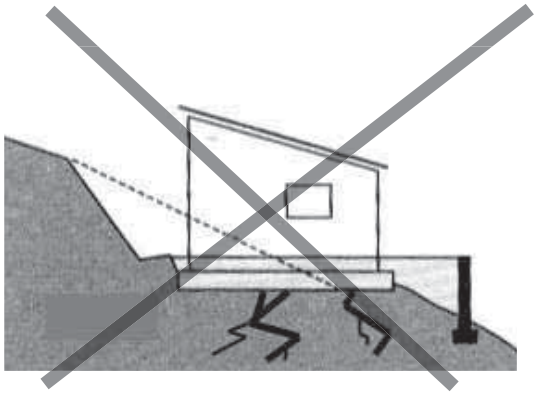
The ground can have differential displacements which are very bad for buildings.
Therefore it is strongly recommended to :

- avoid to build the house on different types of ground or non-homogeneous ground:

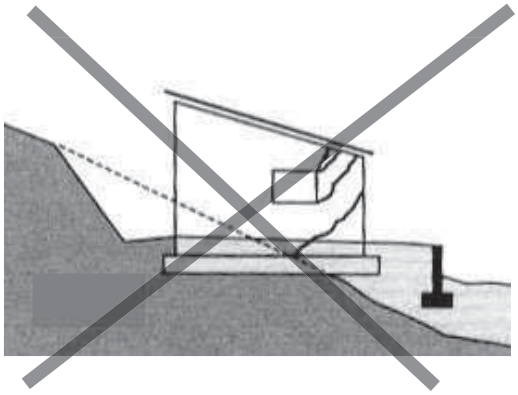


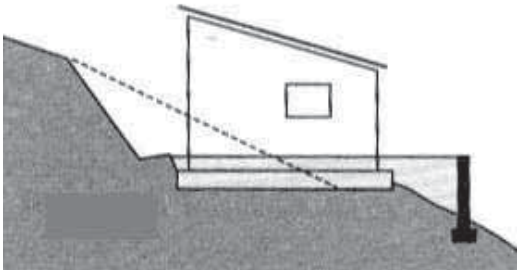


- avoid to build houses on ground with cracks:



- avoid to build foundations with different levels:





LESSON PLAN	GENERALS Building Design	1-5

Participatory approach : time, 30 mn

Objectives: Understand how to reduce the strees in a building by adopting relevant shape and structure..

Method: Help trainees to identify where the buildings will be the more affected in case of earthquake

Trainers	Session	Pedagogical support :	Tools :
One trainer for 7 trainees	To help the trainees to develop their own knowledge on how to reduce the risk of damage on the building by choseen adequate shape and design Part 1 Ø Showing some example of design to the trainees, ask them which part of the building will be the most affected. Ø Make the synthesis Part 2 Ø Ask the trainees to compare differents quality, shape and design of walls or building and to give their impression on the best adapted to resist earthquake Ø Make the synthesis Part 3 Ø Relate the previous assessment to the local building culture Part 4 Ø Synthesis of good practice	Trainer guideline	

Planning
Befoer session
Lecture
After lecture

The shape of the building is the first point to take care of in an earthquake resistant design, since it has a strong influence on the building's response to oscillations, and particularly concerning torsion.

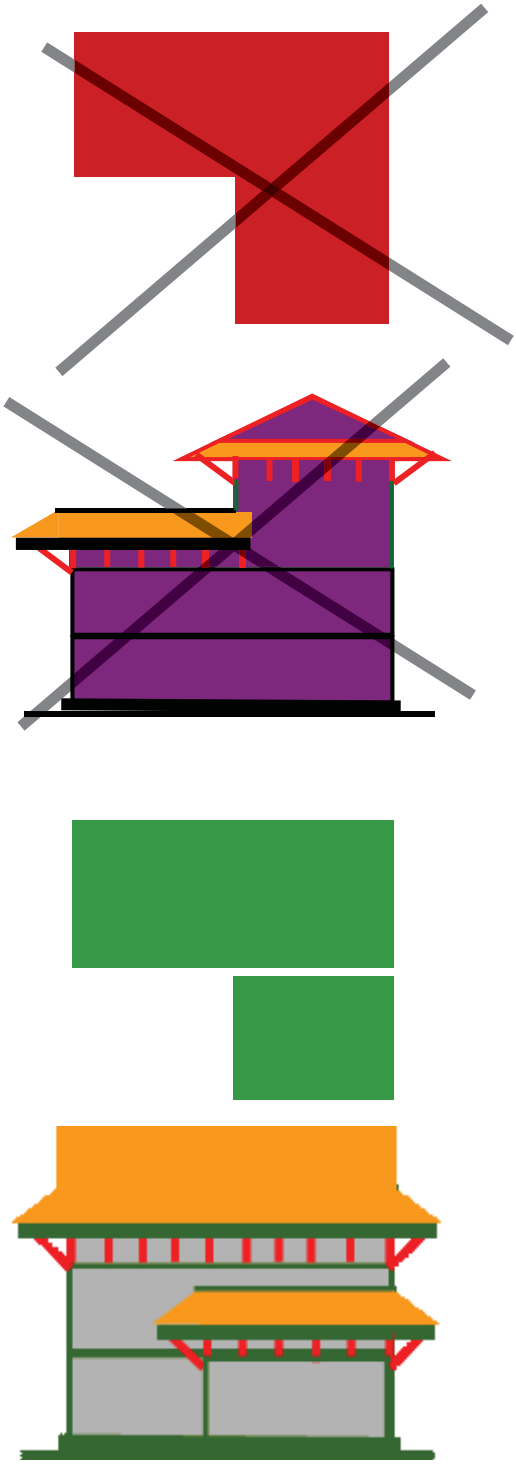
The best shape would be a square plan, but the following principles could be important :

- The building should be symmetrical in both directions, to prevent from torsion phenomenon.

- The ratio between length and width should be less than 3, in order to limit the torsion.

- Inner angles should be avoided, as they are a zone of stress concentration. Therefore, differences of height in one single building should be avoided.

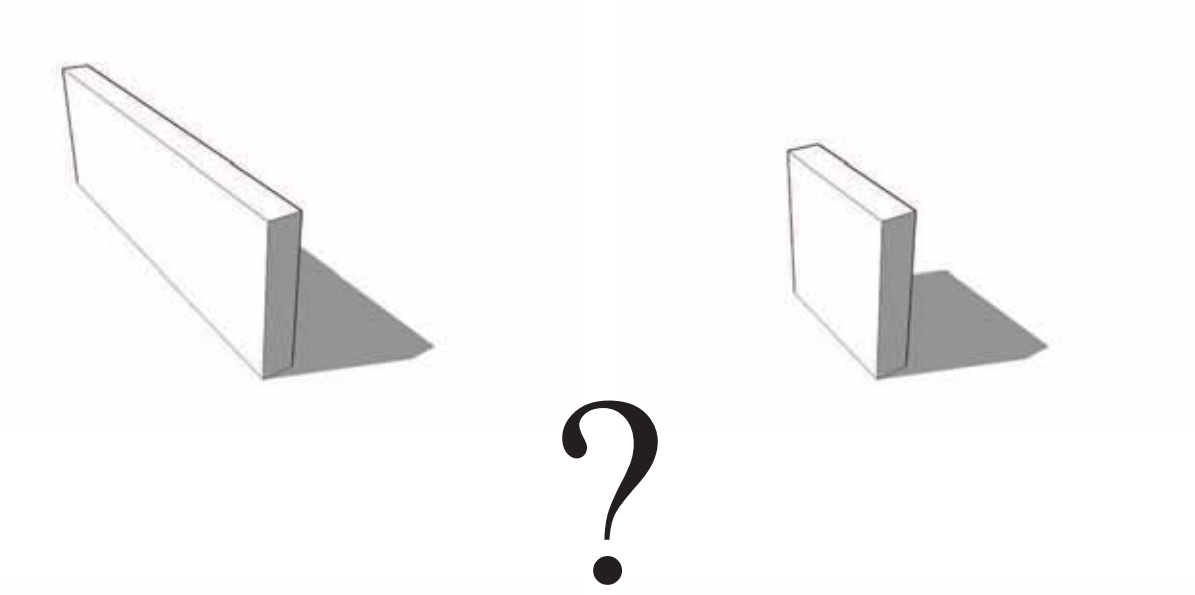
- If the upper points cannot be followed or if complicated shapes are requested, the building should be divided in symmetrical separated parts.



Illustrations from NRCS mason training presentation

Remark:
In case of a building designed with independant autostable elements, those rules might not be mandatory. Nevertheless, they would still improve the general resistance of the building.

Which of the following walls will be the most affected by an earthquake ?



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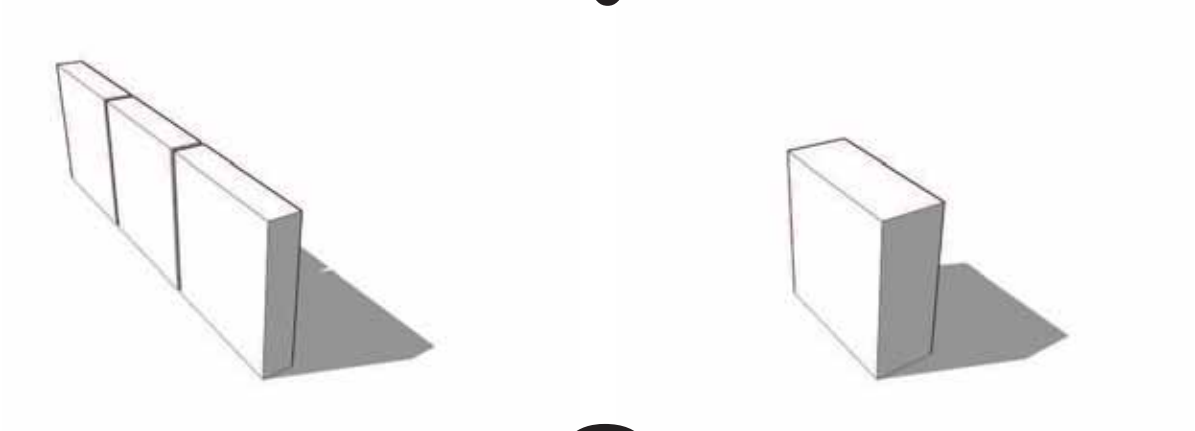

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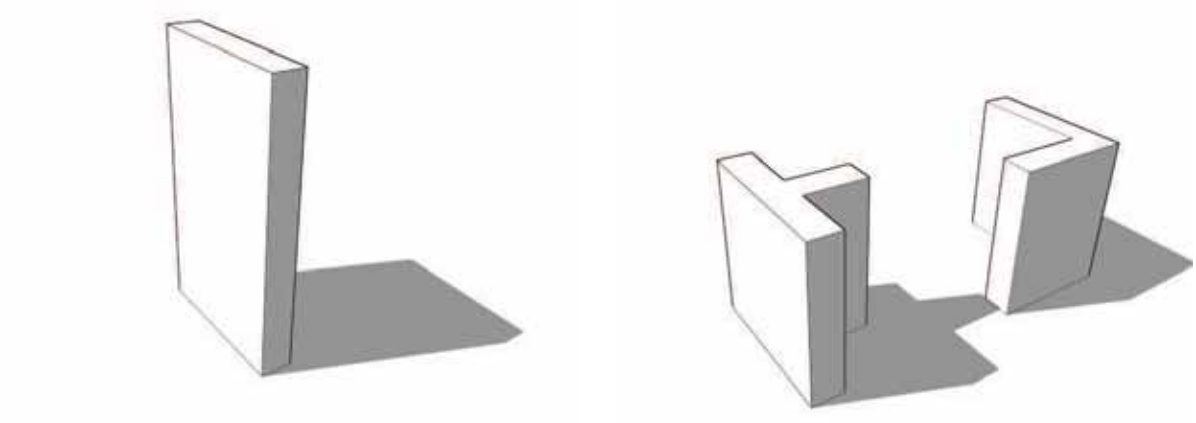
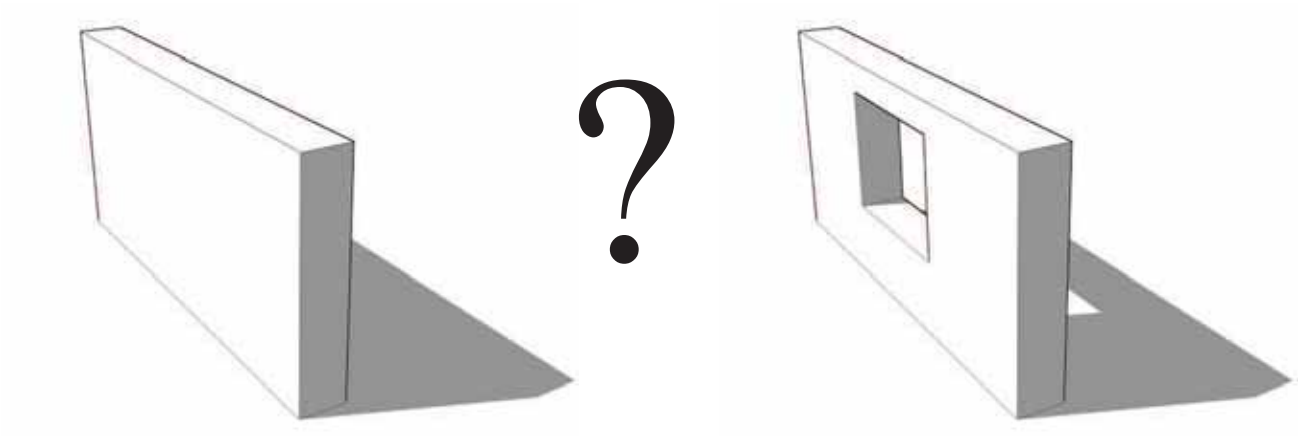
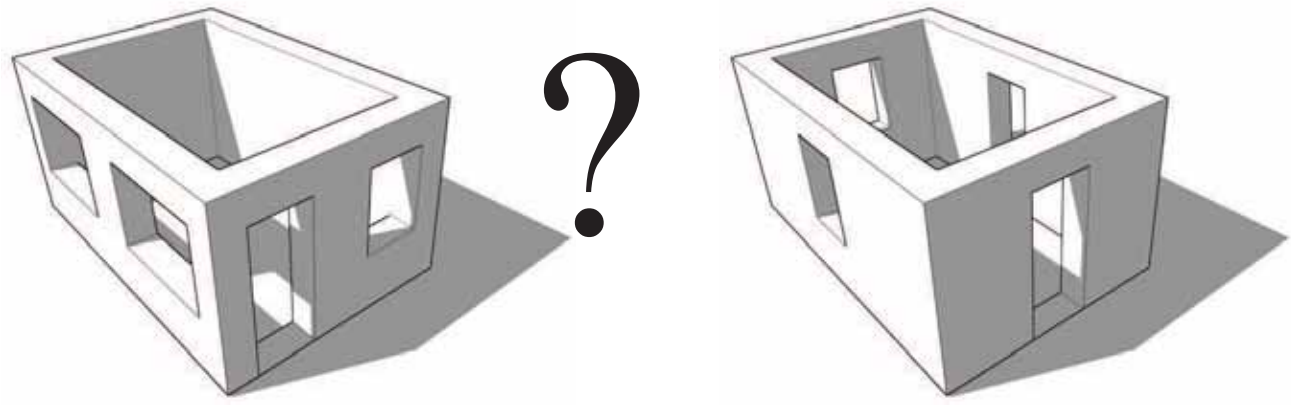
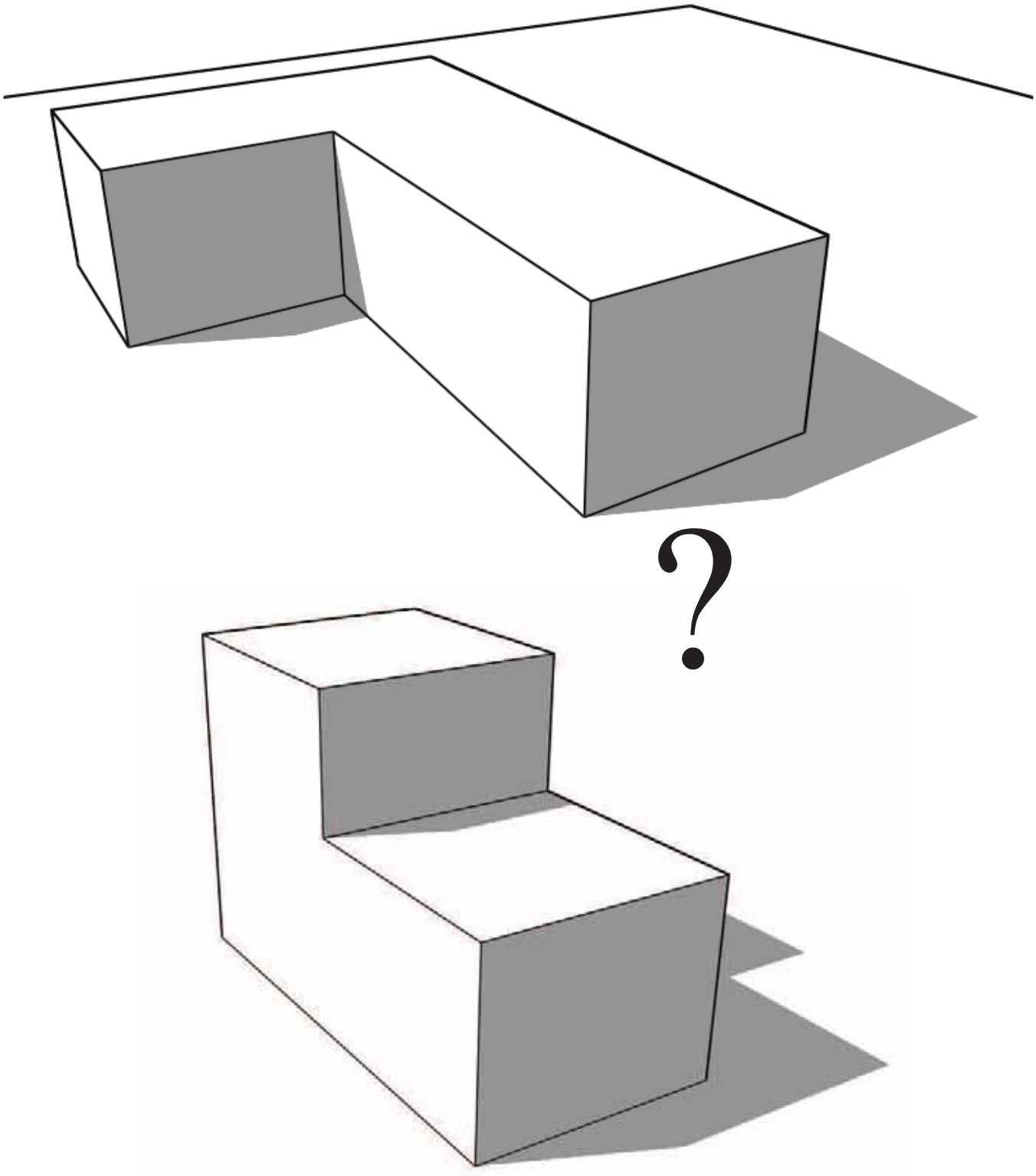


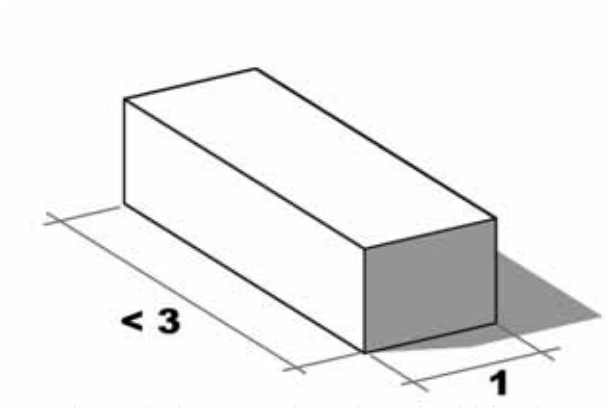
Which of the following walls will be the most affected by an earthquake ?



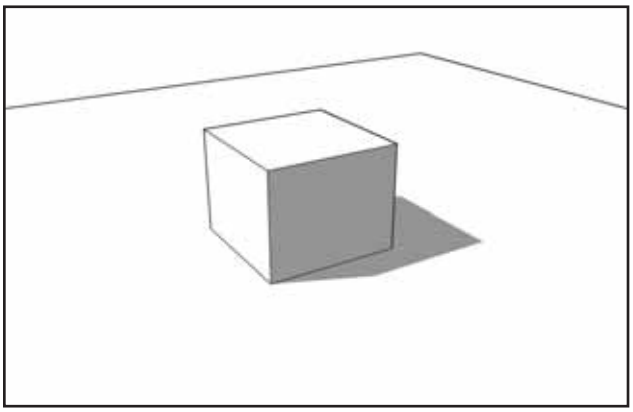


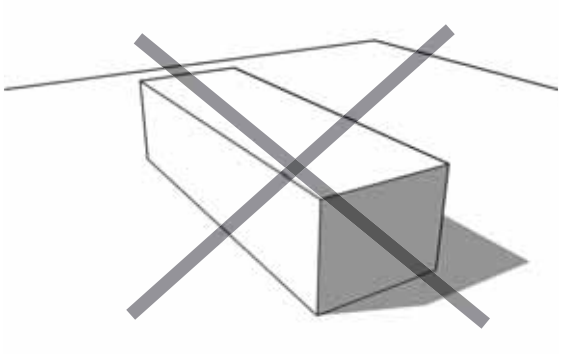
Which part of the building will be the most affected by an earthquake ?

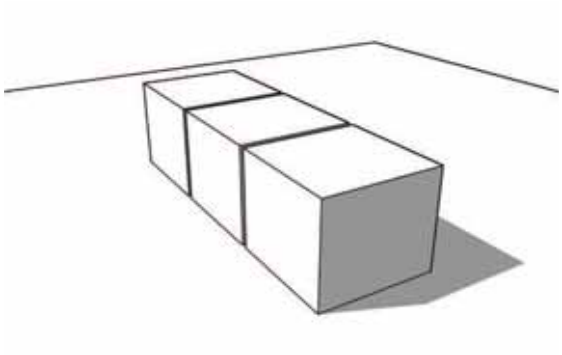


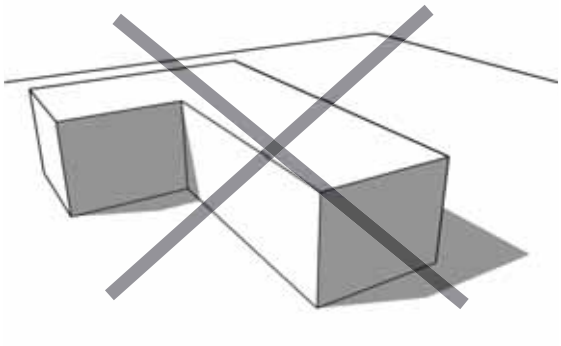


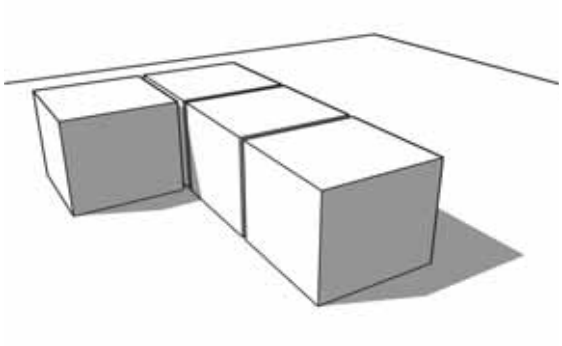
The ratio between length and width of the building should be less than 3.

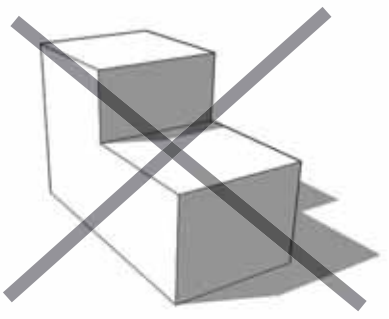


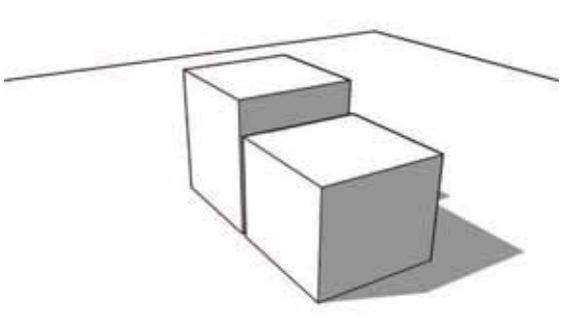












The traditionnal buildings in Dolakha/Ramechhap/ Sindhuli have a good general shape regarding earthquake resistance :

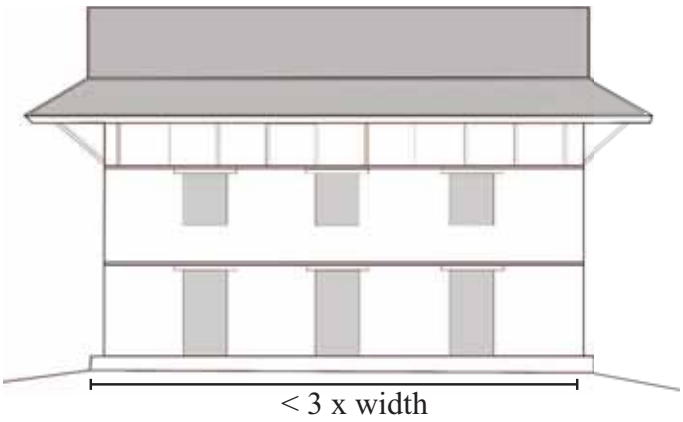
Compact shape

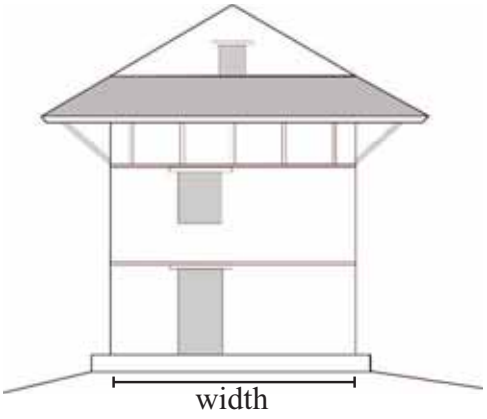
the lenght is around twice the width

the height and number of levels are adequate

Geometry

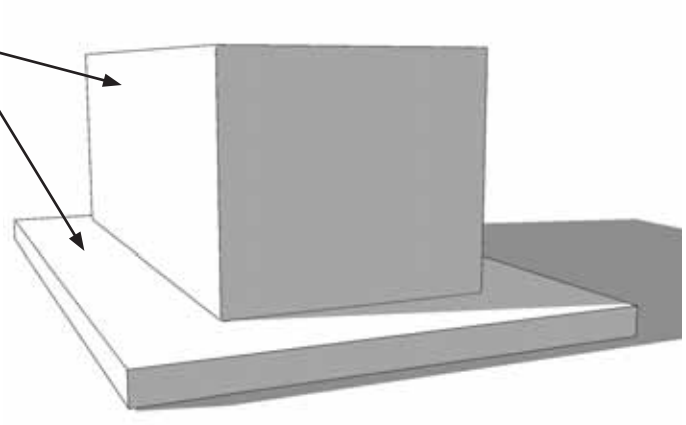
the general shape is symmetrical in a large majority of the assessed houses.





Base:
The house is suported by a massive base.
The base and the house itself work like two independant volumes.

This way, the house is well protected from the risks of floods, running water and splashing from rain. If the base of the wall is not protected from water, the resistance of the stone masonry with mud mortar is heavily reduced.



Session duration: 15 mn

Objectives:
Help trainees to make the best use of the material recovered from the damaged buildings.

Method:
Analyse the characteristics of existing available material and discuss the best way to secure them and to use them back for reconstruction.

Trainer team	Session	Pedagogical support :	Tools :
Lecture One trainer for 20 participant	Preparatory work : Organise a board where can be fixed the pedagogical material (plasticized paper) Organise the room or open site in order to help trainees to have free access to all the documentation fixed on the boards Organise chairs, booknote and pen for participant Translate necessary material in local language. Lecture: Introduction about the topic of the session. With the trainees, identified available local material that could be use for reconstruction purpose. List their characteristics and accordingly, the way to optimise their use for reconstruction (potential use, sizing, sharing out etc.). Give recommendation on storage and then selection of recyclabe material. Give recommendation on how to take care of "modern material " that may be newly used in high quantities in the reconstruction process.	Trainer guideline	

Planning

Before the session:

Lecture

After lecture

In a building, the different elements are submitted to different kinds of stresses and have to carry out different kinds of functions. The different materials that can be used for a building are more or less fitted to answer correctly to each different kind of stress and function.

This technical guide will only focus on materials available locally and at reasonable prices - affordable by local population - in the districts of Dolakha, Ramechhap and Sindhuli, and on how these materials are locally used, transformed and combined to build houses. Other techniques using such materials also exist, but since they are not part of the local culture, their use is much more difficult and may result in creating new problems, either technically or culturally.

Stone

It has a very good behaviour under compressive stress. Difficult to produce but widely available, it is very heavy and therefore difficult to carry over long distances. Elements of stone masonry have a high compressive strength and a very low tensile strength.
It is mostly used for walls and roofing, and sometime also for paving.

Wood

It has a very good strength both under traction and flexion, and its strength/weight ratio is also very good. It is easy to work with, but its use must be well planified as its availabality may be reduced in case of intensive use. It is very sensitive to water and moisture problems, therefore great care is required, when using it near to the ground. It is mostly used for flooring, lintels, roofing and openings.

Bamboo

In the districts of Dolakha, Ramechhap and Sindhuli bamboo is available and commonly used by the population.

Earth (or Mud)

Mud is a very commonly used material in these districts. It is employed as mortar for stone masonry, interior floors, and plasters - both internal as external.

Re-use of stones from destroyed buildings

The stones from destroyed buildings must be cleaned or at least brushed so that they don't present any trace of plaster or mortar. They must not present cracks.

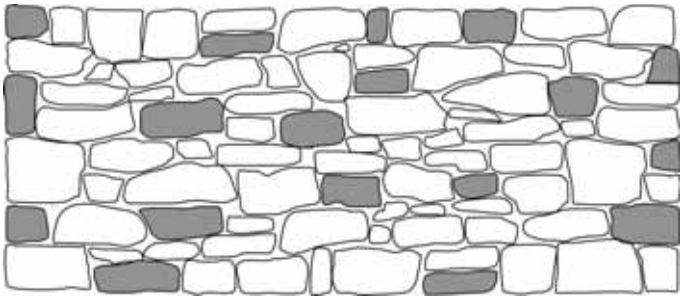
How to organize the storage of stones

The stones to be used in masonry work should be organized on the building site according to their size and shape, as their use will also be according to those features. Having them organized by height will also help on laying regular courses of masonry.

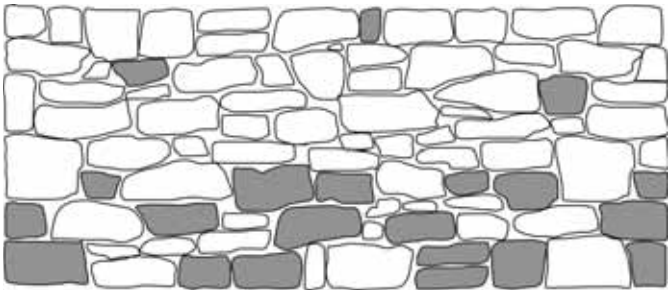
The largest and most regular stones should be used for foundations and for the base of the wall, as they will support more weight. This will also avoid having to lift the heaviest stones to the upper courses, when building the walls. They will be used for the corners too, as it is a weak point of the building.

Long and thin stones will be used as through stones or bond.

It is important to know, at the beginning of the work, the availability of the different size/shape/types of stones, in order to plan for their optimized distribution on the whole building.



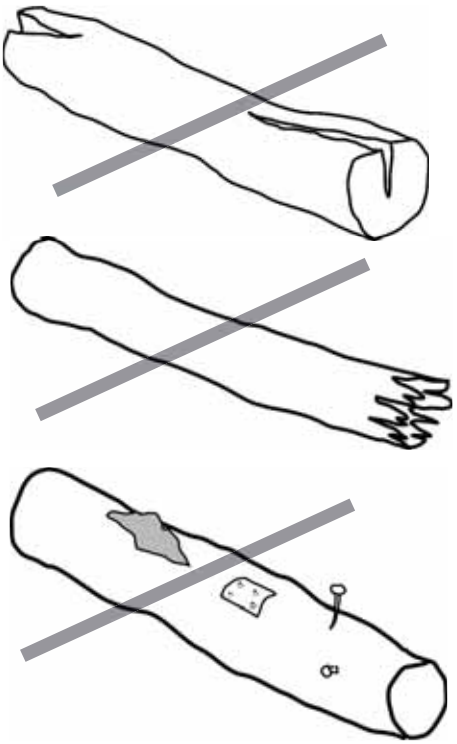
Good distribution of the through stones in the wall.



Bad distribution of the stones in the wall: all the through stones have been used at the beginning, resulting in a weak top of the wall

The different pieces of wood

A wood trunk can be divided with a band-saw into more convenient pieces of wood. The center part of the trunk is the best one and should be used for pieces requiring higher resistance, like beams, while the outer part should be used for planks.



It is better to take older (and therefore bigger) trees and cut it into smaller beams than to use young trees with small diameter. If possible, let the wood dry before cutting it.

Use of recycled wood

Wood from destroyed buildings can be re-used but with great care. The pieces should not be rotten nor present cracks or signs of insect attacks.
If old wooden parts are to be cut with the band-saw, all the dust, mud and nails should be previously removed from it, to preserve the blade's sharpness.

Availability of wood

As for any other material, so the available quantity of wood is limited. Therefore, deforestation can be a serious problem, and not only for the building sector. The use of wood should be rationalized to prevent waste and the cutting of trees should be well planned, to prevent shortage of this resource.

Wood treatment

Regardless of its resistance and durability, wood is nevertheless quite vulnerable to moisture and xylophages (organismes that feed on wood - namely mushrooms or insects such as termites). Therefore, a sequence of good practrices should be carried out to ensure its proper performance. These practices include:

- cutting of trees at the proper season
- thorough drying process
- proper stocking procedures
- water-resistant/anti-xylophage treatment

Wood treatment

In the districts of Dolakha, Ramechhap and Sindhuli, no particular wood treatment methods were identified, since traditionally, construction works used locally available hard wood, that, being very resistant, wouldn't require further specific treatment than seasoning (cutting at the good season and proper drying procedures).

Recently, with the scarceness of hard wood, soft wood has been employed in construction, but the inherent treatment that this type of wood requires has not yet been integrated in current local practices, so the wooden elements of the buildings quite exposed to possible deterioration through moisture and/or insect attacks.

Nevertheless, some traditional treatment methods, somehow present in the three districts, include :

burning the surface of the wood pieces, or having it heavilly smoked, to protect it from insects.

placing neem (azadirachte indica) leaves buried all around the base of wooden posts, when these are also buried, to create a "barrier" that prevents insects from coming close to the wood;

painting the wood pieces with used/burnt lubricant (from motor).

These methods could be enhanced, to achieve wood treatment levels adjusted to the quality of the available wood - the burning process is hard to control and not very effective against insects; the neem method is quite limited, and further essais and studies are required to mesaure the effectiveness of neem-based solutions in wood treatment; lubricant is effective for moisture, bur not completely for insects, and it is quite hazardous for health, so it should be used only on wood pieces/faces that are not in contact with the inside of the house.
Likewise, other treatment methods could be applied - such as the ones using boron solutions - keeping the execution/ressources/price at affordable levels and maintaning acceptable health/safety standards during the handling of the products, the execution of the treatment, and the effects of having the treated elements inside the house (vaporous toxicity, etc.).

NB: Further information on wood treatment methods can be found in the annexes to this technical guide.

Sawmill in Dolakha: non-optimized seasoning methods

Plywood boards receiving waterproof treatment (with chemical hazardous products). Wood pieces do not receive this or any other kind of treatment.

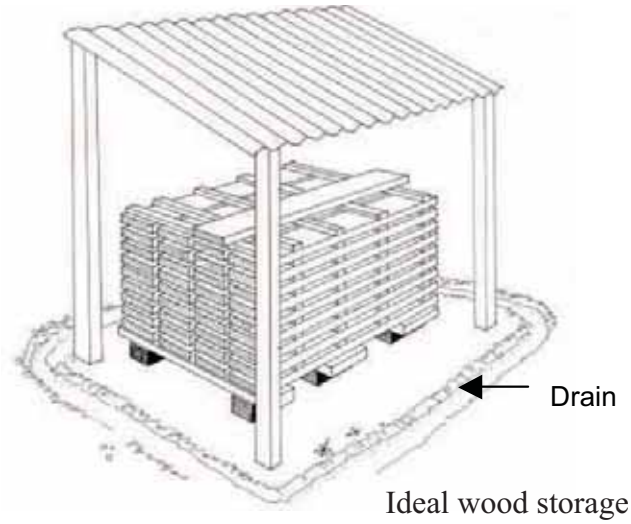
Wood is traditionally smoked (or even superficially burnt as a protection)

Stocking of the wood

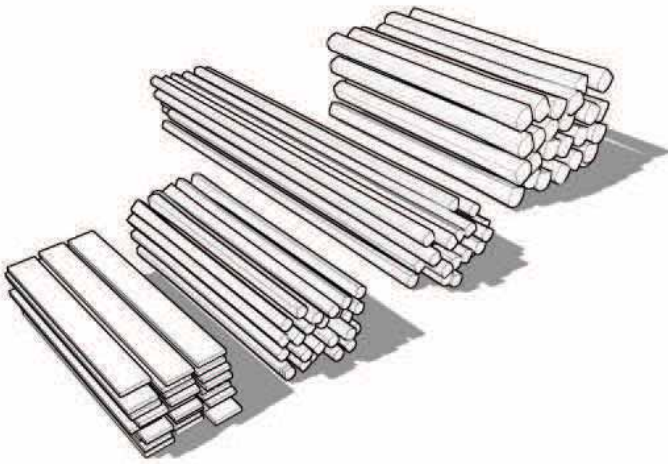
Wood should never be stocked directly on the ground, to prevent it from rotting.
It should be stacked on stones in a ventilated space and protected from the rain.
The different wood pieces should be laid horizontally and separated from each other (with a wood or bamboo piece, for example), to improve the drying process.

It is important to know the availability of the different pieces of wood at the beginning of the building process, to plan for its optimised use.

It is therefore recommended to organize the storage of the wood parts according to their size, shape and type.



Ideal wood storage



Stock according to size/shape/type of wood pieces

In the districts of Dolakha, Sindhuli and Ramechhap, bamboo is widely available.
Bamboo has a fast maturation (3-4 years) and is locally used mainly for scaffolfings, light construction, partition walls and roofing structure.
After the recent earthquakes, we have observed many temporary shelters quickly built out of bamboo stripes and bamboo poles.

Bamboo varieties identified during field assessments :

Local name	Size (diameter)	Uses
Dungle bans	small	roofing
	medium	boundary / inside walls
	big	poles
Taru bans (more resistent)	approx . 10 cm	poles

If treated, bamboo can be used for structural elements. Such as for wood, economical & low-toxicity solutions (like borates soaking and diffusion) bamboo treatment methods could be applied at sawmill level, or at householders groups level, if technicians are trained.

It should be considered as a very usefull alternative, where wood is scarce and/or too expensive.

Photos 2-3 : ABARI (Adobe and Bamboo Research Institute)

Mud is widely used as a construction material, in rural areas, as it is locally available, free of cost and well known by local builders. It also provides good acoustical (sound) and thermal (heat/cold) properties, providing comfortable and affordable living space.

Field assessement analysis demonstrates high level local skills and know-how on mud used as:

*mortar for stone masonry
*plaster for interior and exterior walls
*partition walls
*light walls (wattle and daub)
*floors

Different techniques and practices were clearly identified for the different types of plaster observed, whether it is internal/external and/or dressing/finishing ones :

A study on the local practices would allow a better understanding of the possible uses of local soils. Such study should be extended to several points of view : technical, economical, social and cultural.

From that wide-scope analysis, it would be possible to bring out some proposals for improvements based on the existing local practices.

Some observed practices, among others, include the use of vegetal fibers and cow dung to reinforce the plasters.

Photo 3 : Randolph Lagebach

During emergency reconstruction process, many temporary shelters have been built by the familys whose houses have collapsed, or that don't feel safe going back to their damaged houses because of the visible unsafety indicators presented by those buildings or by the site where they are/were located.

This emergency reconstruction brought large quantities of materials, that should not be neglected for reconstructing the houses.
Amongst those materials, there are:

- corrugated iron (CGI) sheets
- wood in small sections
- tarpaulin

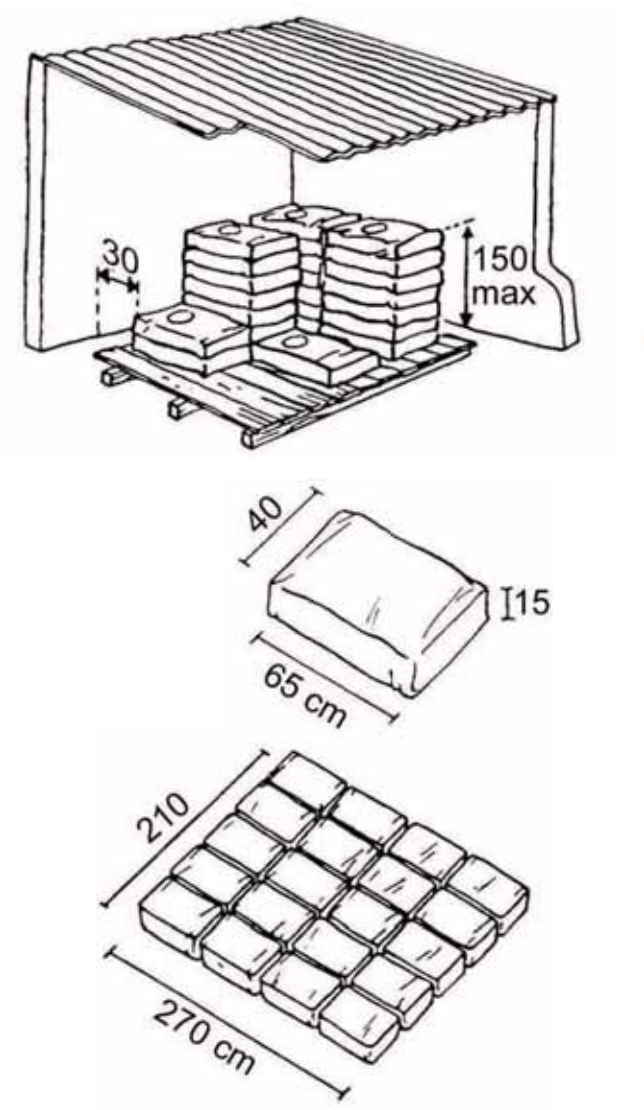
The CGI sheets, in spite of their stainless quality, should be stored away from moisture to ensure a longer and proper conservation.

Cement and lime

Cement and lime may be available. Both of them can be used to improve the resistance of the earth plasters and mortars to water, and their compressive strength. They can also be used to make floor slabs, for example.

Bags must be kept in a locked place, insulated from the ground and distant from the walls, to protect them from moisture.

It is recommended to shake the bags every 3 weeks, especially during the rainy season.



LESSON PLAN	GENERALS Local seismic culture	1-23

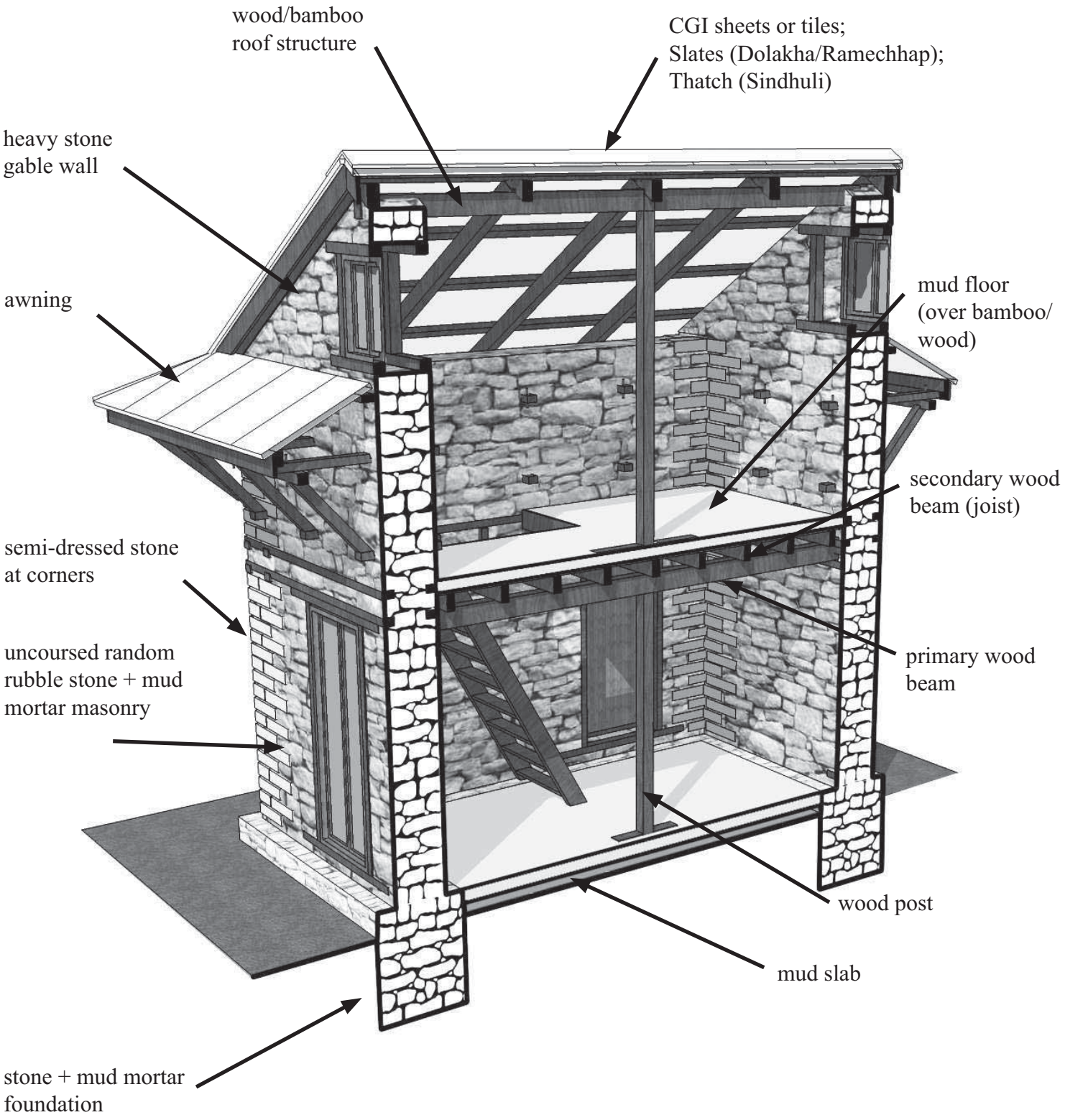
Session duration: 20mn

Objectives: Assess the existing identified LSC.

Method: Analyse the local LSC in relation with the knowledge acquired by trainees during the previous lecture.

Trainer team	Session	Pedagogical support :	Tools :
<u>Lecture</u> One trainer for 20 trainees.	<u>Preparatory work :</u> Ø Identify the existing LSC in the area Ø Document it Ø Find similar examples existing in other part of the world <u>Lecture:</u> Ø Describe the general structure of vernacular architecture (stone, wood structure, flat roof). Ø Give back to the trainees the basics principle of the sismic culture developed locally.	<u>Demonstration</u>: Trainer guide:	

Planning
Before session
Lecture
After lecture


wood/bamboo
roof structure
CGI sheets or tiles;
Slates (Dolakha/Ramechhap);
Thatch (Sindhuli)
heavy stone
gable wall
awning
mud floor
(over bamboo/
wood)
secondary wood
beam (joist)
semi-dressed stone
at corners
uncoursed random
rubble stone + mud
mortar masonry
primary wood
beam
wood post
mud slab
stone + mud mortar
foundation

Some of the houses in the districts of Dolakha, Ramechhap and Sindhuli resisted the earthquake. Here are some of the features found in those that ensured their resistance :

Regular shapes
- symmetrical houses
- small openings not too close to the corners.

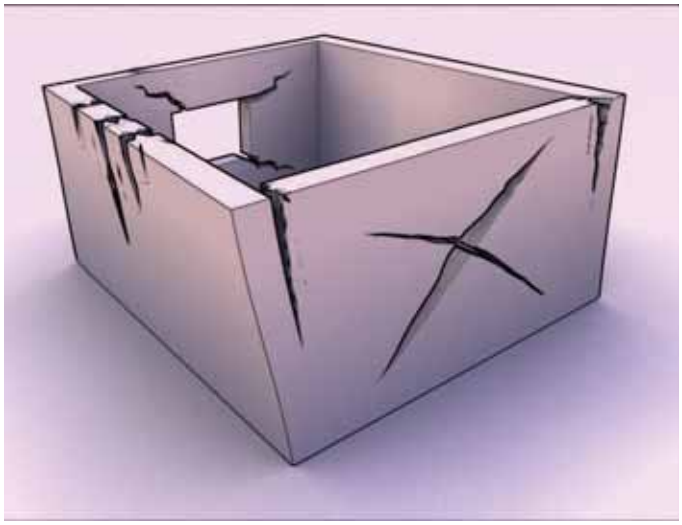
Good quality stone masonry
- Good laying of stones, proper mortar filling
- Use of corner stones and through-stones

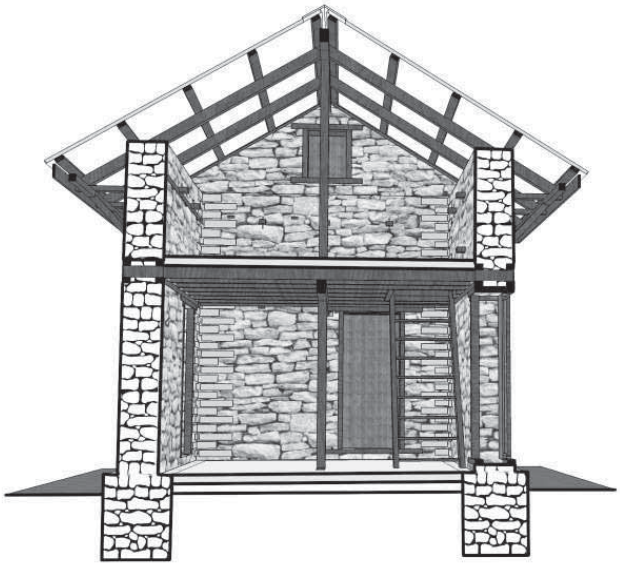
Wooden elements in the walls

Presence of wooden elements in the masonry, that dissipate vibrations, and thus ensure a better resistance of the walls.

The stone wall alone has some weakness against seismic loads, because of its lack of tensile strength and also because the absence of confinement may allow some stones to fall apart, which can dramatically reduce the wall's stability.

In the local construction culture, walls are supporting the floors and the roof : The joists lay on the walls (going all the way in), and on a central longitudinal primary beam that is supported by one or several wooden posts.
An horizontal wooden band, at each floor level, helps to tie walls together to enhance the box effect. When made continuously throughout the lenght of the walls and properly connected at the corners, that band improves horizontal bending resistance and contributes in preventing the collapse of walls.





Combination between stone walls and wood flooring and roof

LESSON PLAN

FOUNDATIONS

Definitions and function

2-1

Session duration: 60 mn theorie; 1 day practice

Objectives: Understand role, behaviour in static conditions and in dynamic condition (case of earthquake) this in order to help trainees to make conscious decisions when they will be on the job.

Method: Assess the trainees understanding in the related subject
Debate on information collected

Practice on the field (on the real building or on demonstration sample)

Trainer team	Preparatory work :	Pedagogical support :	Tools :
One trainer for 7 trainees on theorie One trainer for three group of 7 trainees on practice	Ø Identify construction opportunity or site for sample demonstration Ø Clear the site and make preliminary work if necessary. Ø Supply necessary material and tools for on site training. Size to be related to the number of trainees Session: Part 1: normal conditions Ø Ask trainees to describe the role of the foundation in the common situation Ø Ask the trainees to list the different quality the foundation itself and the material used to do it should have Ø Make the synthesis o Transfer the load from the structure to the good soil § In contact with the good soil (stable and with enough compressive strengh) § Compression resistance § Good practice in masonry § Stability o Water resistance Part 2: Behaviour in seismic conditions Ø How the ground movements are transferred to the top structure. Ø Rigid approach: consequence on the superstructure Ø Flexible approach: o How to reduce the energy transferred from the soil to the super-structure. o How to ensure the stability of the foundation components or to avoid that a foundation's partial collapse affects the entire superstructure Part 3: step by step of the good practice of dry stone massonry Part 4: Practice on site	Demonstration: Trainees guide:	Massonry tools

Planning
J- 5 weeks
Lecture
After lecture

Definition

The foundation is the part of a construction below the ground level.

Function generals

The foundations allows an equal distribution of the weight of walls and roof into the ground. They should be strong, resistant to compression, and ensure full stability for the walls, as well as limit the moisture and capillarity problems.
To achieve this functions, they should be constructed on hard and good soil and designed in order to keep the material used for its construction resistant and durable - this regarding particularly the risk of water and moisture penetration in these materials.

Seismic behavior

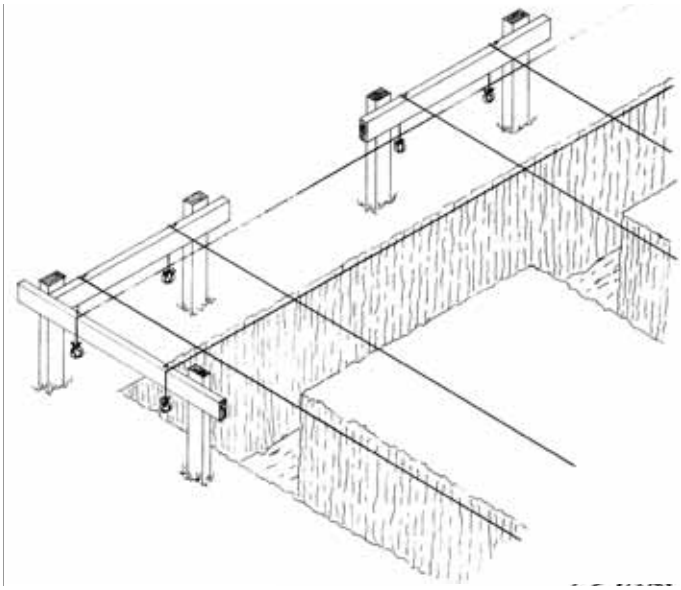
The foundation quality is particularly important in earthquake prone areas, as the foundation is the link between the ground and the structure. During an earthquake, the foundation transmits on to the structure not only vertical loads but horizontal ones too.

In the flexible approach, the foundation is able to deform like the rest of the structure. It can absorb some energy by friction, and its flexibility should prevent the differential displacement to reach the whole structure, like in the picture (Turkey).

In a flexible approach, a breakage of the foundations doesn't mean a failure of the building

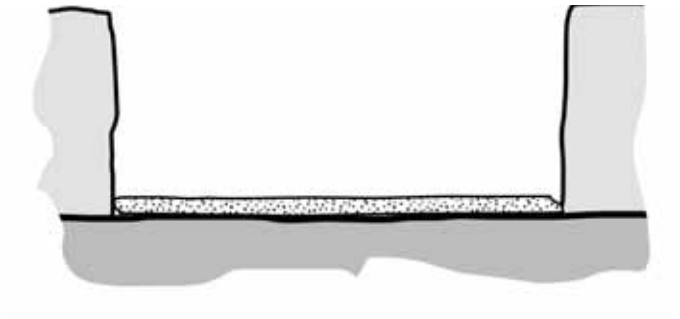
The trench is necessary to reach the firm stone soil. It serves as a formwork to cast the foundation.

It is essential to dig the trench neatly, following the alignment with the string.
In case there is no need for digging to reach hard ground, the place for the foundation must be very clean.



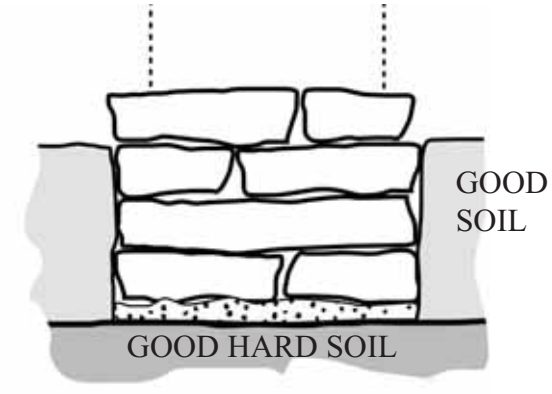
Once the trench is completely excavated, its bottom should be covered with a 2” to 4” layer of sand.

This sand layer allows the foundation stones to rest firmly on hard ground and to distribute the load evenly.

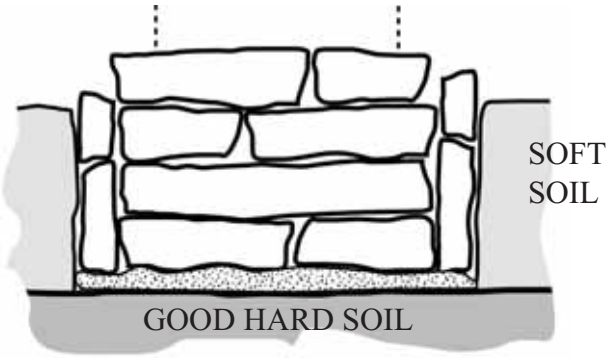


Lay the stones in horizontal layers and check the level of each course by measuring the distance from the line. Use stones as big, flat and regular in height as possible, and lay as many through-stones as possible - the best would be one over four, in each layer, but do the best with the material available.

Bring the foundation at least 4" above ground level
The foundation should be at least 2" larger than the walls, on each side.



To help stones in the fondation to be properly confined within the trench, some flat stones can be used to face the vertical side of the trench.



Stability: The foundation ensures the stability of the wall by distributing the load evenly on the firm ground. Vertical stones ensure that foundation stones remain in place and do not penetrate in the ground	Friction: The stone foundation allows some dissipation of energy through friction. The surfaces of the vertical stones contribute to this process.	Maintenance: Among other advantages, making the foundation larger than the wall allows an easier maintenance of the plasters.

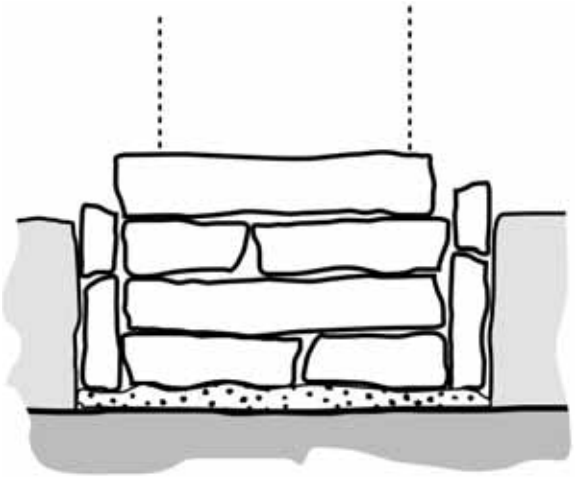
A particular care will be taken, concerning the interface between the foundation and the wall. A partial breakage or collapse of the foundation should not cause the wall to collapse.

Several options can be made for this purpose :

Flat stones

The foundations can be finished with a top layer of the biggest and flattest stones available.

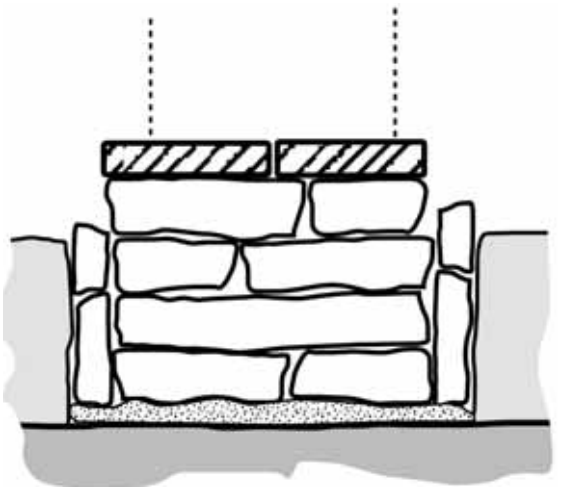
A simple method to provide Damp Proof Course (DPC) in rural areas is to use empty bags of cement or jut bags and a small quantity of bitumen: First give one coat of bitumen on the leveled footing, then lay the empty bag, cut at the required size, then finish the DPC with a final coat of bitumen over the empty bags.
A thick plastic sheet can also be used for this purpose.



Wooden planks

The foundations can be finished with a layer of wooden planks.
It is strongly recommended that this wood is thoroughly treated previously to its setting on the foundation wall.

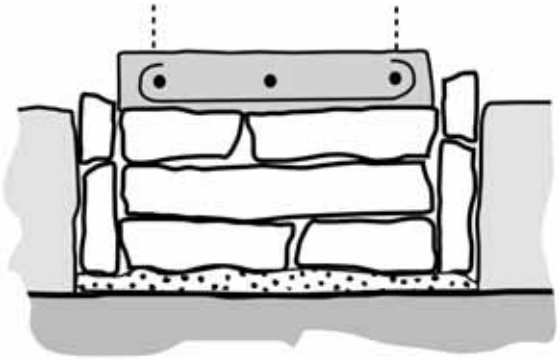
For this solution, the DPC should be put under the wooden planks, thus also protecting them from any moisture rising from the ground, by capillarity, through the foundations.



Stability: The flat stones / wooden planks allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations. It prevents a partial collapse of the foundations to affect the walls.	Friction: The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction (with higher friction between wood and stones than between stones).

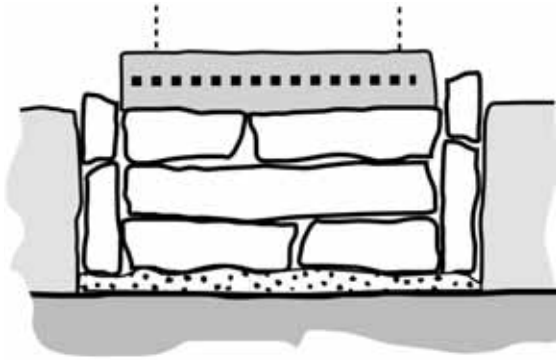
Cement mortar

Finish the foundations with a layer of mortar. This layer must be perfectly horizontal and is let to set before building the wall.



The mortar can eventually be reinforced with rebars, as in reinforced cement concrete (RCC) principle.

The mortar can also be reinforced with wire mesh. This wire mesh should be cut at the width of the wall, and the parts used to get all the lenght of the walls must be overlapping. Tying them with wire could help keeping them in place, when pouring the mortar.

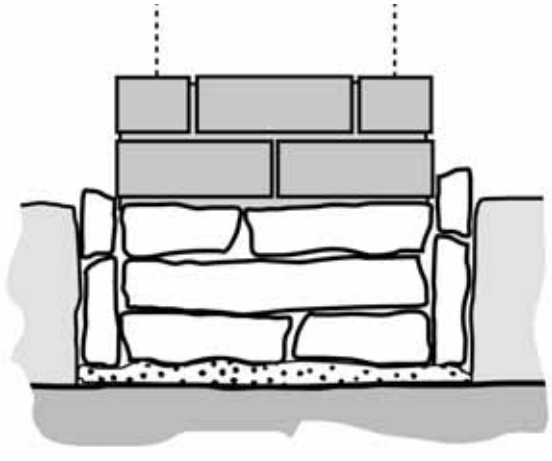


Either with or without reinforcement (rebar/wire mesh), the mortar layer will also play a role of DPC, due to the water-repellent properties of cement.

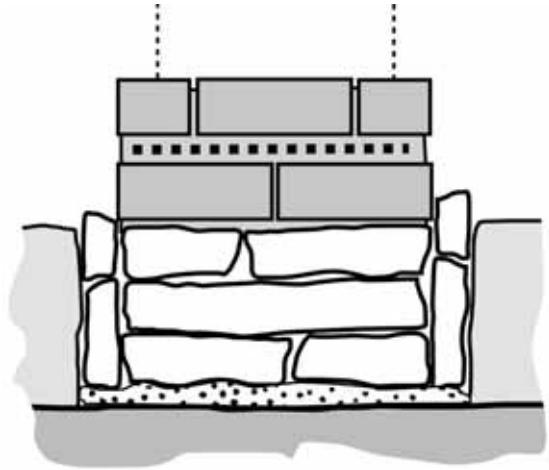
Stability:	Friction:
The mortar layer allows a good start of the walls, with a well aligned first layer, and a good distribution of the load on the foundations. It prevents a partial collapse of the foundations to affect the walls.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction. The mortar can dissipate some energy through breakage.

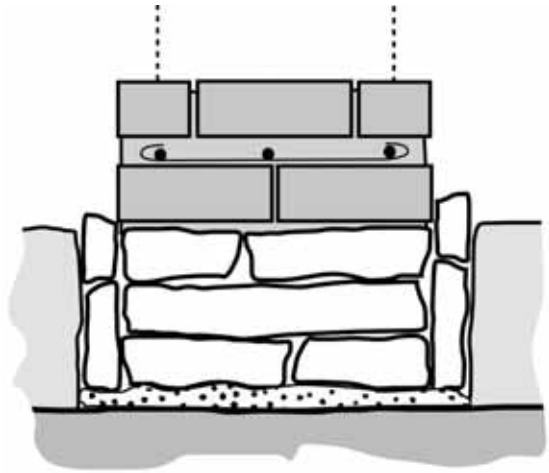
Bricks

Finish the foundations with two layers of fired bricks, laid with mud mortar.
These layers must be perfectly horizontal.



As an option, an intermediate layer of cement mortar, reinforced with either steel rebars or wire mesh, can be put between the brick layers.





Stability:	Friction:
The bricks allow a good start of the walls with well aligned first layer, and a good distribution of the load on the foundations. It prevents a partial collapse of the foundations to affect the walls.	The wall is partly disconnected from the foundations and the flat surfaces allow a better dissipation of energy through friction. The mortar can dissipate some energy through breakage.

LESSON PLAN

MASONRY

The stone wall

3-1

Session duration: 30 mn theorie; 1 day practice

Objectives: Understand the two concept; stability of the work and dissipation of the energy given by he earthquake. Through this understanding, help the artisans to be conscious of the good practice to apply when they will be on the job.

Give an overview of the worldwide knowledge (good practice and LSC) as well as the result of research that can help to improve stability of the wall, dissipation capacity of the wall, and security for the inhabitant.

Develop improved design that will integrate international LSC

Method: Discussion on existing local good practice for wall stability

Discussion on how to improve the stability of the wall (describe how problem occur, understand why, try to develop solution.

Discussion on local know how related energy dissipation

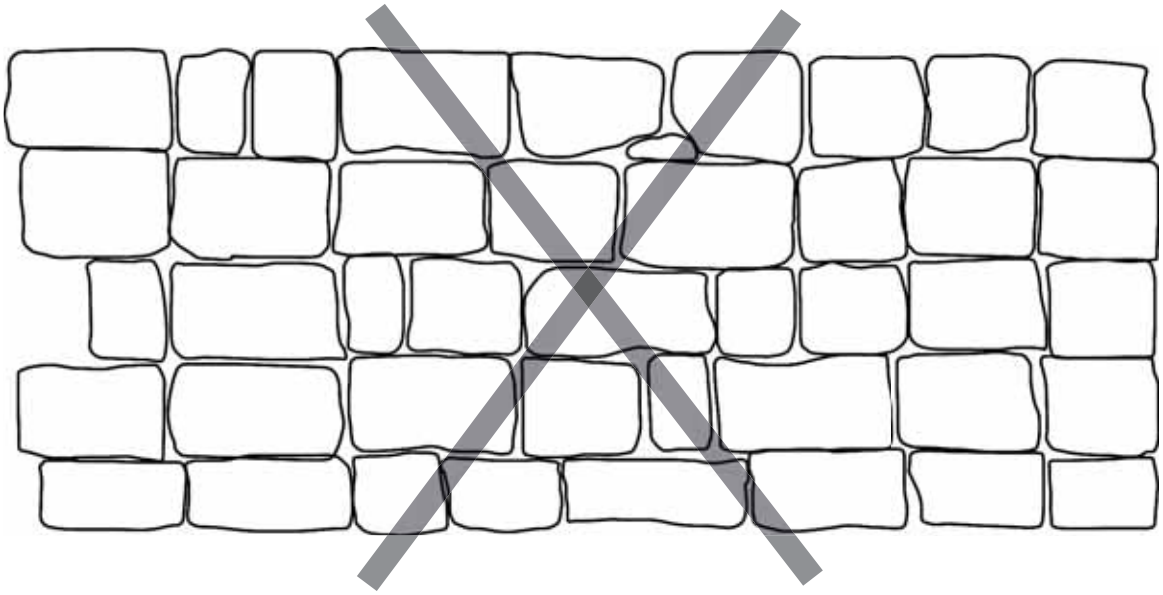
Discussion on how to improve the dissipation capacity of the wall (describes how phenomenon is happening, understand why, try to develop improvement on the existing).

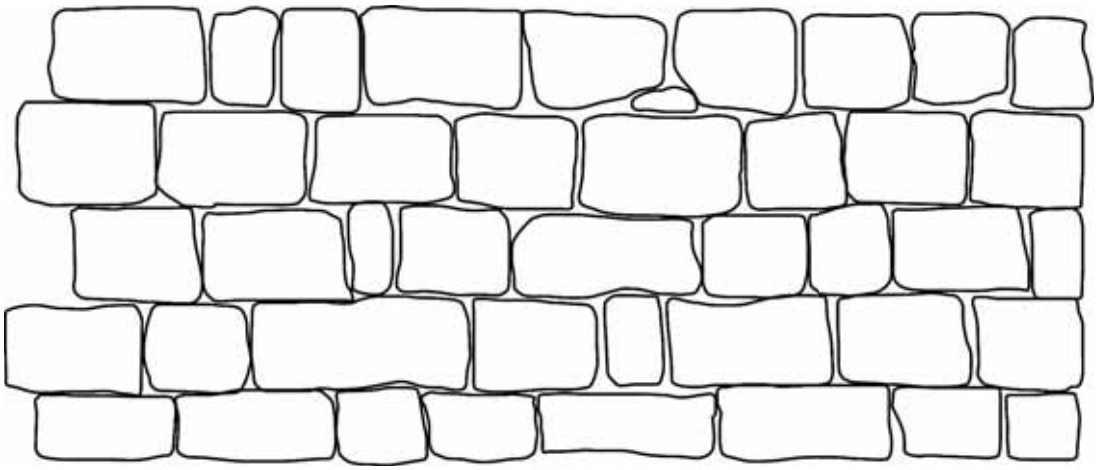
Practise in the field

Trainer team	Preparatory work :	Pedagogical support :	Tools :
One trainer for 7 trainees on theorie	Identified and document local good practice and LSC Illustrate local good practise and LSC with international good practice and LSC Illustrate international good practice and LSC in similar context and condition.	Demonstration	Massonry tools required for stone massonry
One trainer for three group of 7 trainees on practice	Session: <u>Part 1; role in static condition; stability</u> Ask the masons to share together on the stone masonry good practice (they can illustrate physically what they are talking about using existing walls or stone). Ask them to identify main problems they are facing to apply good practice. Ask them to identify the main problems stone walls are facing and to give their understanding of the raison of these problems Ask trainees to develop potential improvement on the existing Illustrate some of the international good practise. Relation thickness / high Practice on site: <u>Part 2; behaviour in dynamic condition;</u> Trainees analysis: Ø Building comportment Ø Rigidity approach Ø Flexibility approach <u>Part 3; Dissipation; the LSC</u> Ask the masons to share together on local LSC (they can illustrate physically what they are talking about using existing walls or stone). Ask them to specify the reason of each detail they are talking about. Ask them to identify main problems they are facing to apply good practice. Ask them to identify the main problems stone walls are facing and to give their understanding of the raison of these problems Ask trainees to develop potential improvement on the existing Illustrate some of the international good practise. <u>Part 4; Discussion about the differents technical details developed in the guideline</u> Ask trainees to give their ideas on the variuos proposed technical details. Give the trainees an overview of potential improvement. <u>Part 5; Doors and windows anchorage</u> The existing The needs The main rules to be observed and why Anchorage of doors and windows	Trainees guide	

Planning
J- 5 weeks
Lecture
After lecture

Joints between stones must not be on top of each other.



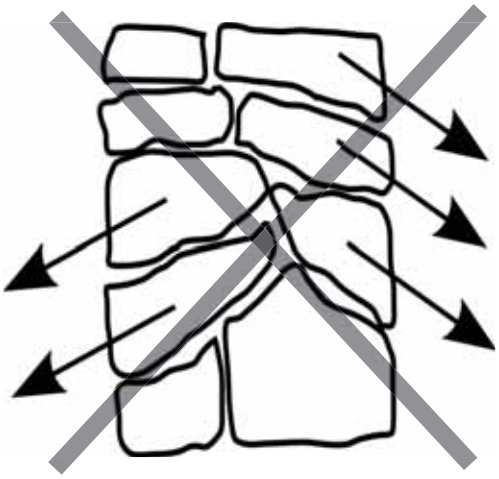


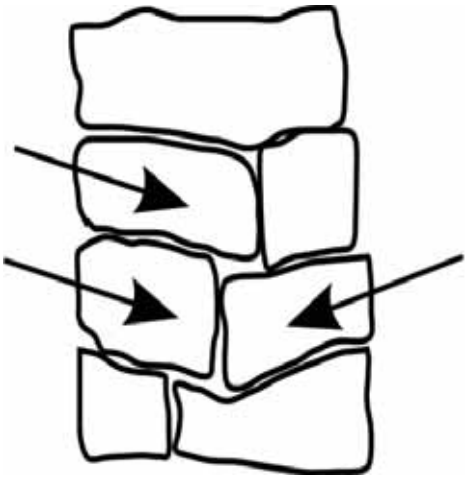
Stability:	Friction:
Discontinuity of the vertical joints ensure a good cohesion of the wall and prevents it to split.	The more link between stones, the more friction, allowing a better dissipation of energy.

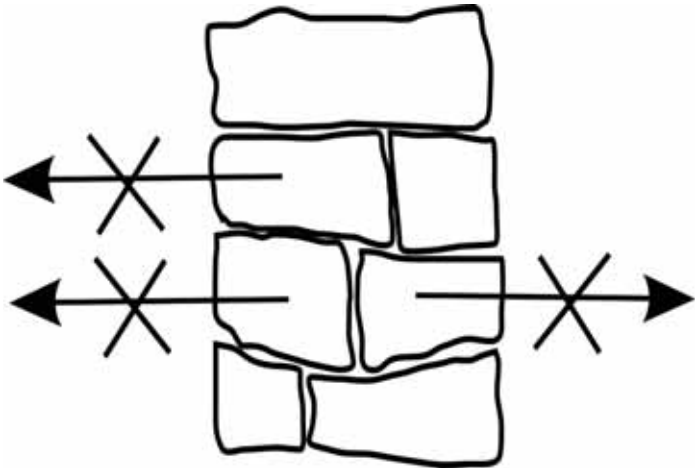
Stone wall - Stones leaning

The stones should be slightly leaned to the center of the wall, to prevent them to fall out.

The aesthetic aspect is not the most important for the choice of the stone placing. The stones should be placed to be the most difficult to be removed.

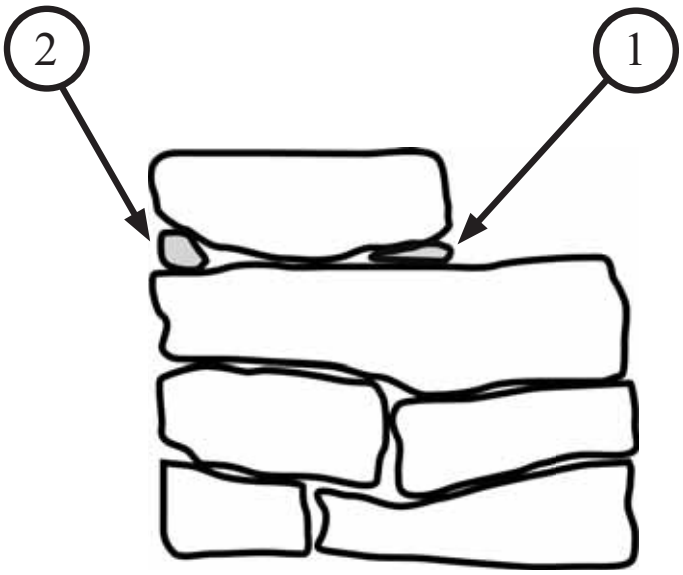






Stability:	Friction:
In case of slight movement of the stones under seismic stress, they tend to stay in place.	The fact that the stones remain in place longer under seismic stress allow them to dissipate energy through friction for a longer time.

The blocking stone must be inside the wall so that it cannot be removed or fall. The outside stone is putted after, but even if removed, the big stone must remain in place.



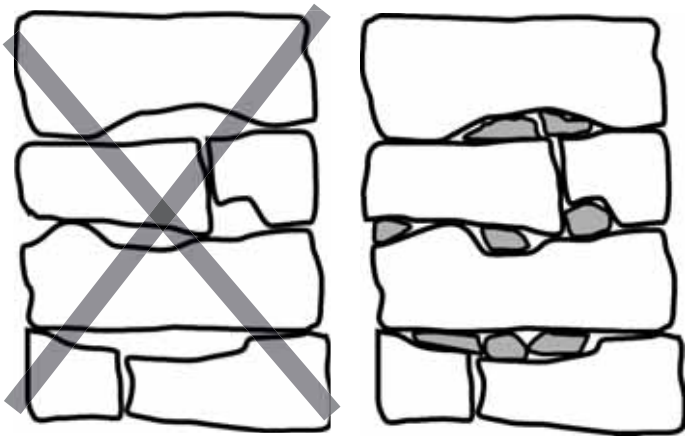
The contact surface between the stones must be as big as possible.

Small stones are used to fill the gaps and increase friction but big stones with flat sides are better.

Every stone must be blocked in all the directions.

Once the wall finished, more small stones can be added on the faces of the wall to stabilize the bigger stones.

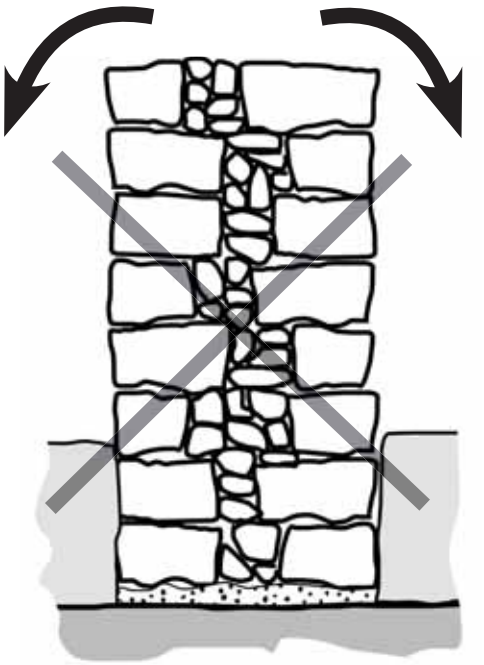
Even when using mortar, small stones should be put in every gap, so that the contact between stones is bigger and thus also the friction increases.
This will also avoid excessively thick morter joints - that would probably fissure during the drying process.



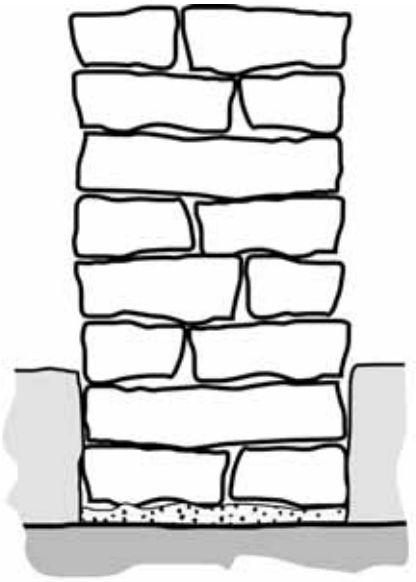
Stability:	Friction:
The more contacts between stones, the more each stone will be blocked and stable.	The more contacts between stones, the more friction and dissipated energy.

The two sides of the wall must be linked with long stones - *through-stones* - to prevent the opening of the wall. The more through-stones there are in a wall, the best it is.

Stones from one side should, as much as possible, be laid on the stones on the other side.



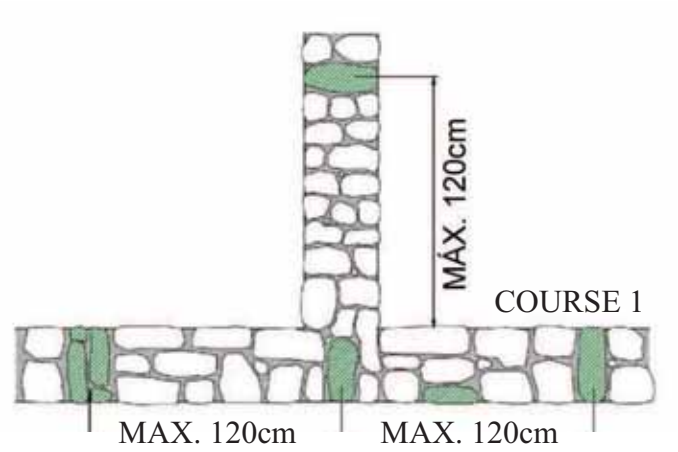
Either for through stones, corner stones or any other masonry elements, every stone should always be laid on its biger surface (base bigger that height). This is a basic principle of any good stone masonry and plays a major role in EQR, adding stability to the wall.

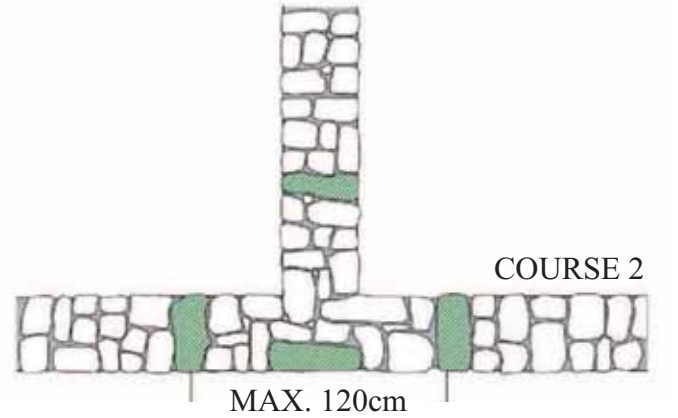


Stability: The through stones ensure the stability of the wall by connecting the two faces.	Friction: The more link between stones, the more friction, allowing a better dissipation of energy.

Through-stones should be placed at a maximum distance of 4ft (1,20m) between them.

Special attention should be given to “U“ shape connections, and through stones play a major role and should not be neglacted in this type of masonry connection.



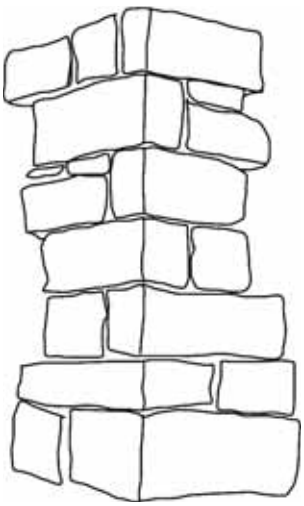


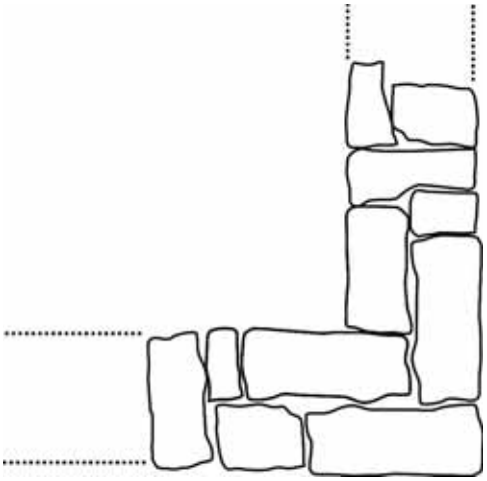
picture : building in Singati, after the 2015 (May 12th) Earthquake in Dolakha, showing very few through-stones and the “opening” of its walls, resulting in partial collapse.
Notice that horizontal seismic bands kept the whole from collapsing, in spite of the absence of part of the core of the wall - that plays a structural role.

The corners of the walls are a weak part of the building, especially under seismic stress. Particular attention should be given to the laying of the corners.
Big stones should be used as often as possible, at every course.

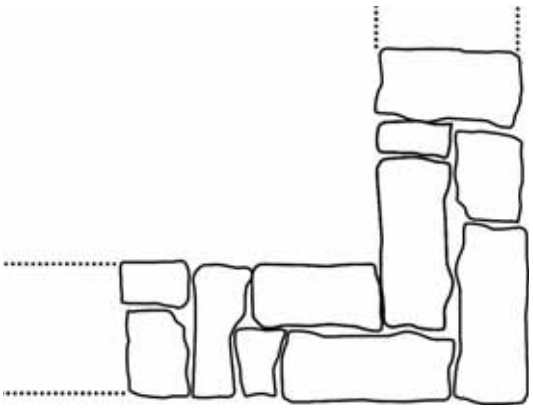
Long stones must be used both inside and outside the corner.

The corner stones must be crossed so that no vertical continuity can exist in joints.





COURSE 1



COURSE 2

Stability: The through stones in the corners prevent the wall to open.	Friction: The best stones with flat sides provide bigger contact surfaces, and thus more friction and dissipation.

Being one of the fundamental architectonic elements, the walls play several roles :

Structural

The walls support the roof's weight and eventualy also the upper storeys.

Thermal

The walls protect the occupants from cold and heat, and eventualy regulate temperature variations.

Aesthetical

The form and look of the wall is of first importance for the general aesthetics of the building.

Social

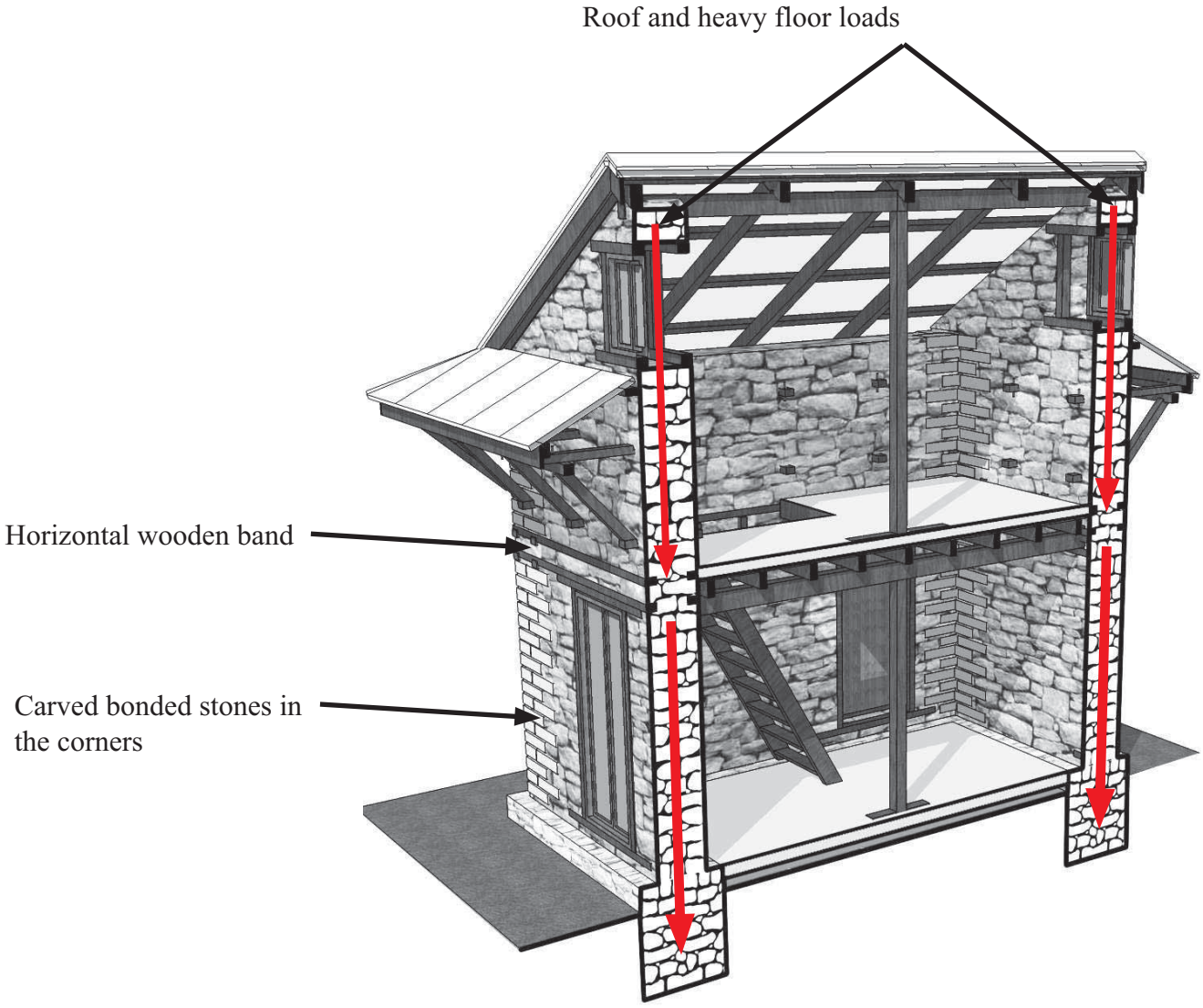
The wall preserves the intimacy of the occupants, by separating the public space from the private, and the spaces devoted to the different functions.

In this structure, the resistance of the walls is achieved through a flexible/dissipative approach. The stone/mud mortar masonry walls can have post-elastic deformation, dissipating a lot of energy through friction.

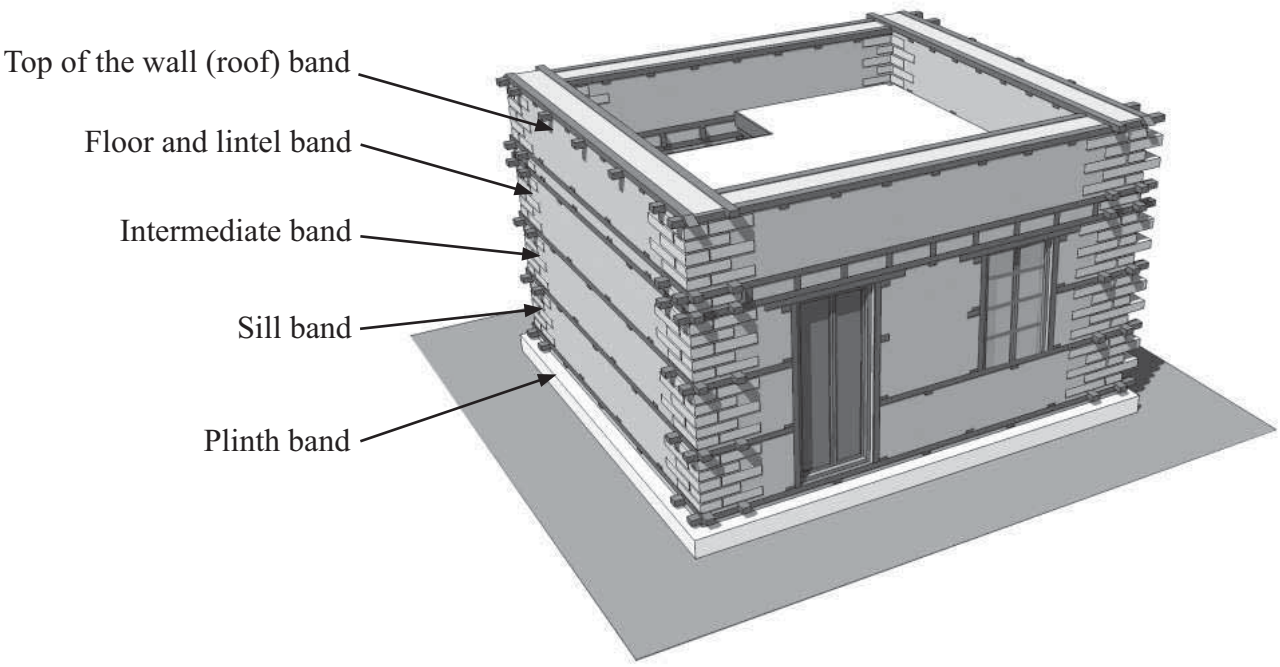
The horizontal wooden bands divide and confine the walls into smaller elements, and allow friction between these elements and the wooden bands.

Corners :
The horizontal bands avoid corners from collapsing. A particular care of the bonding of carved stones in the angles improves the resistance of wall corners.

The roof and floor loads (weight) help confining the masonry walls.



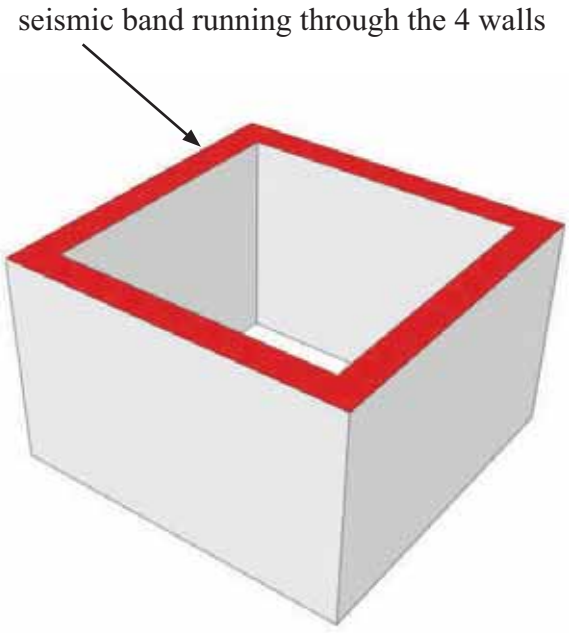
Seismic bands provide critical earthquake-resistant provision in a stone masonry building by tying all walls together and acting like a ring or belt. Seismic bands can be constructed using reinforced concrete (RCC), timber or bamboo. They must be located at different levels of the wall: plinth, sill, lintel, floor and top of the wall (roof).
Proper placement and continuity of bands and proper use of materials and workmanship are essential for their effectiveness.

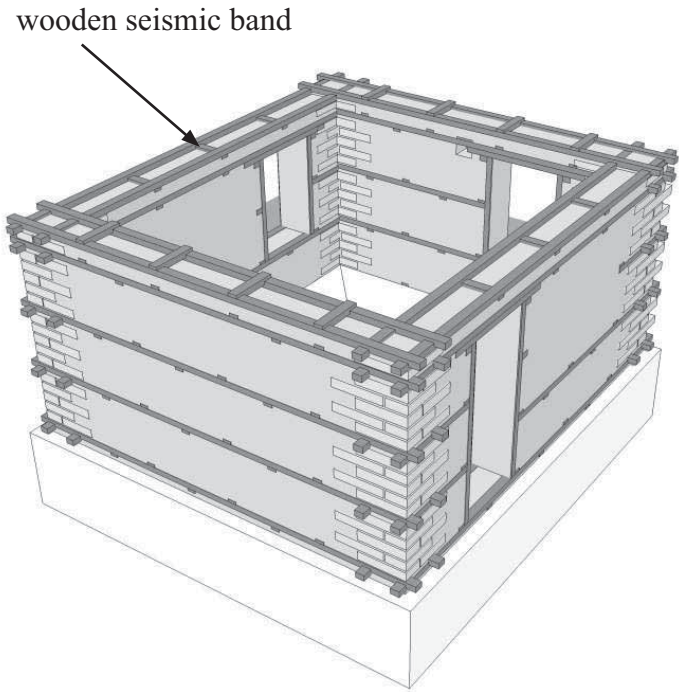


The corners of the building are the most affected parts by the torsion stresses. It is therefore recommended to increase their tensil strength. This can be achieved through:

Seismic bands

Continuous horizontal wooden elements. A seismic band does not act as a rigid diaphragm, therefore the wall is still able to deform.

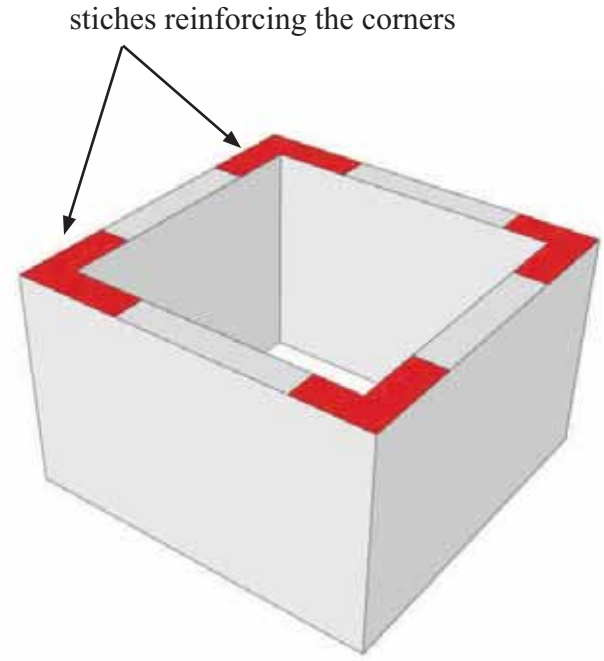


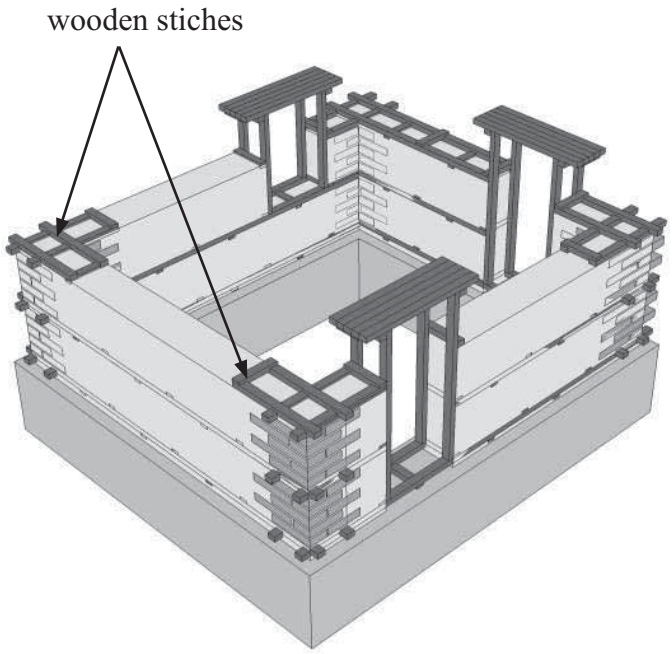


Stability: The seismic bands maintain the corners together even in case of cracks or partial collapse.	Friction: The friction between wood and stones is high, allowing a good dissipation of energy.

Specially when there is short availability of wood, it is possible to use “stiches” in the corners, in between seismic bands.

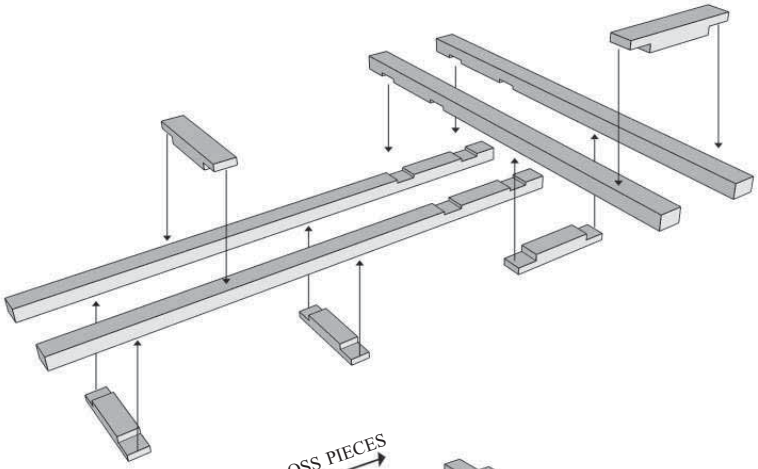
Even if not as effective as seismic bands, this elements will nevertheless still reinforce the corners of the walls, with the main advantage that the use of wood is less important.

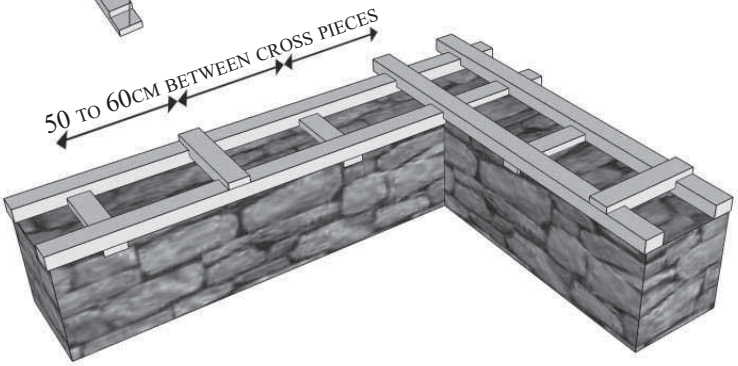




Stability: The stiches maintain the walls together even in case of cracks or partial collapse.	Friction: The friction between wood and stones is high, allowing a good dissipation of energy.

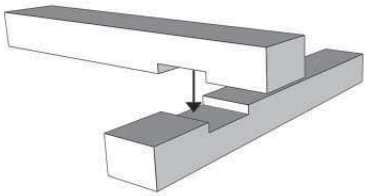
Proper spacing between the cross elements and good connections to the longitudinal ones will ensure the effectiveness and the resistance of the band.



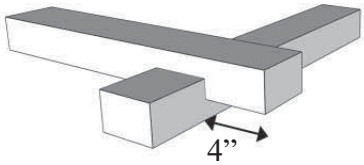


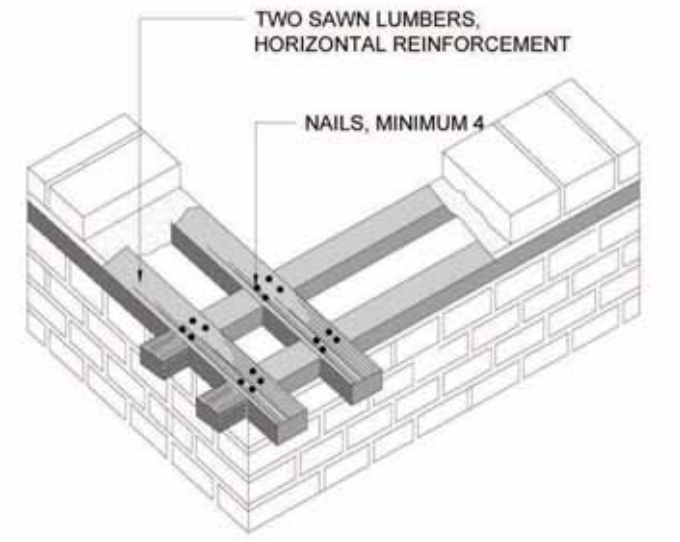
To keep the wood elements from loosing their resistance and breaking easier, the cuts for the connections should not go deeper than 1", down to a maximum of 1/3 of the thickness of the wood pieces.

The overlapping 4", coming out of the wall at the corner connections, prevent those connections from failing due to earthquake caused horizontal and vertical movements.
Straight cut connections that collapsed after the earthquake have been observed during field assessment missions.



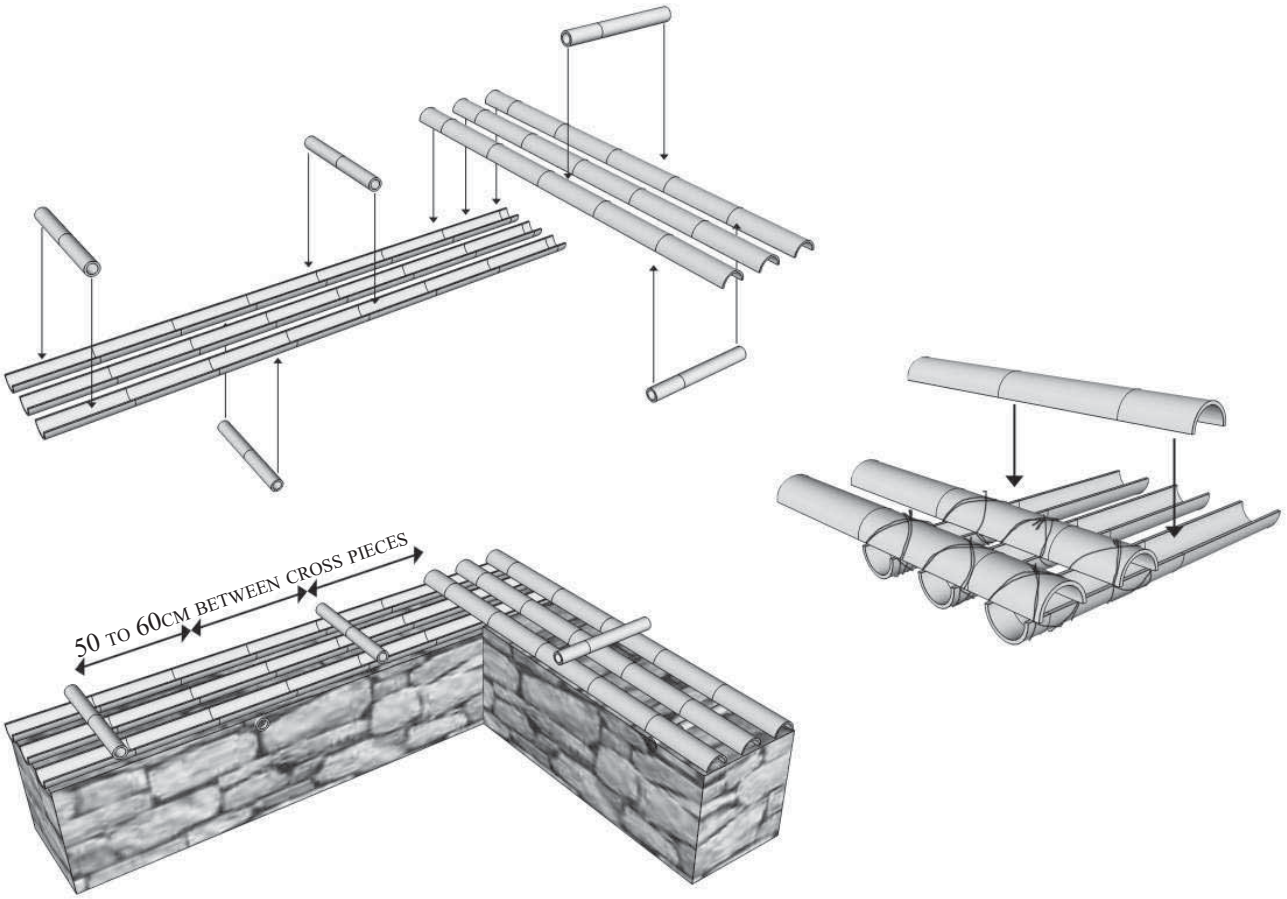
This overlapping parts should be thoroughly treated, since they are exposed.





Detail of a timber band from NBC 203

Full-round or half-round bamboo can be used to create a bamboo band. Connection between bamboo poles can be realized using galvanized steel wire or ropes.



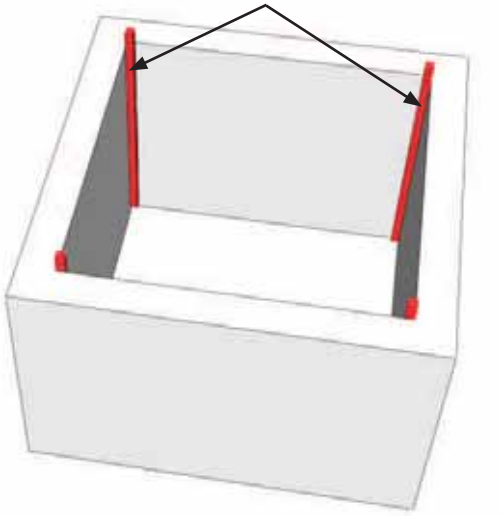
Bamboo elements don't have the same behaviour as wooden ones, since bamboo has low compressive strenght, though it has a very good tensile strenght.
Nevertheless, it remains a good solution, specially in contexts where wood is scarce or unaffordable.

An eventual crushing of the bamboos (specially when using half-round cut bamboo elements), caused by the masonry walls weight, should not be considered as a major problem, since the flatten strips keep their tensile resistance.
In some constructive cultures around the world, bamboos are flattened before used for this kind of elements, to allow an easier setting and more simple connections.

The horizontal elements - seismic band and stiches - can be connected by vertical elements.

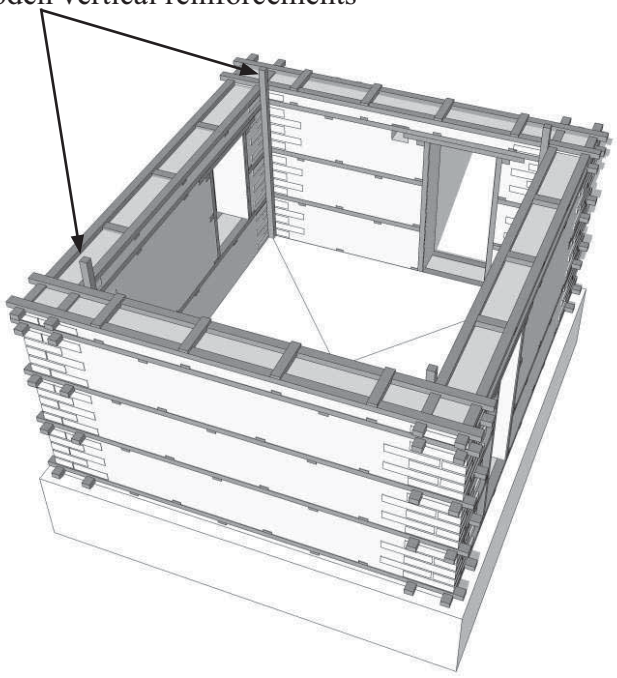
Whether they are in wood or bamboo, this vertical elements should not be placed inside the wall, as this would not allow a proper laying of the corner stones, and they should be placed at the corners, in the internal side, to keep them protected, namely from rain.

vertical reinforcement in the corners



NB: Since the principle of EQR through horizontal seismic bands lays on dissipation - so that the vibrations coming from the ground get dissipated along the building's height and get to its top in quite "weaken doses" - the inclusion of any vertical elements that connect these horizontal bands (the dissipators) seems contradictory to that dissipation principle. These vertical elements seems more likely to make sense on a rigid approach (such as RCC structures) than on a flexible one, such as the one in this technical guide.

wooden vertical reinforcements



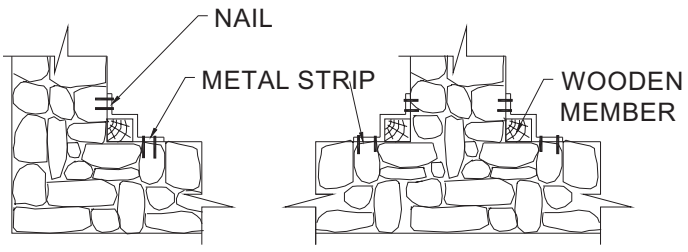
No thorough scientific studies were conducted on this issue, but the authors of this guide tend to believe that better results would come from adopting one of the following procedures:

- not setting any vertical elements connecting the horizontal bands, thus keeping their full dissipation performance;

- use small section elements, with a certain flexibility, that wouldn't jeopardize the whole flexible approach, thus transmitting as little vibrations as possible between horizontal bands. Further more, these vertical elements should be connected to the horizontal bands with flexible strips that would avoid major transmission of the vibrations, but would still hold them in its place.

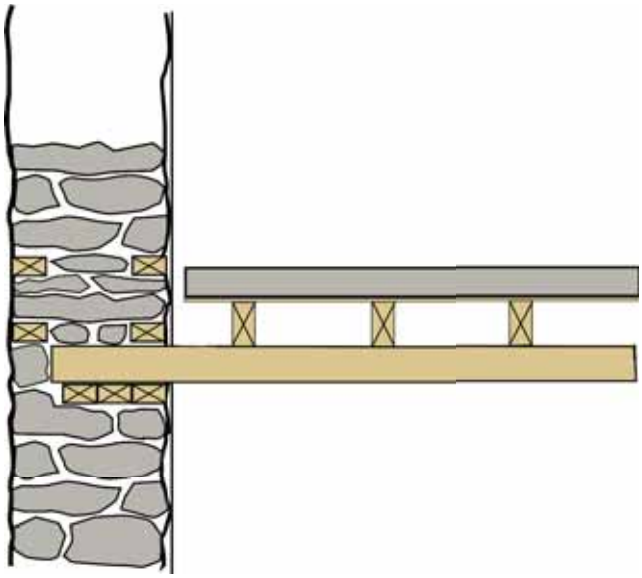
These recommendations remain valid, whether the vertical elements may be of wood or of bamboo.

Ultimately, vertical reinforcement elements could be introduced at the corners (and eventually some more along the walls lenght), but with the single purpose of helping to support the floor structure and eventualy also the roof. If so, the thickness of these elements should be considerable, to allow them to be effective, andany connections to the horizontal bands should be either avoided or very flexible, to avoid the vibration transmission.



timber for vertical reinforcement detail from NBC 203

Field assessment analysis suggest that one of the major causes of masonry disrupture and, ultimatelly, wall collapse (specially for gable walls) is the “punch-effect” caused by the movents of the floor central beam.



In order to minimize these effects, this beam should be set on the masonry upon a wooden element that :

distributes the load of the floor evenly throughout the wall;

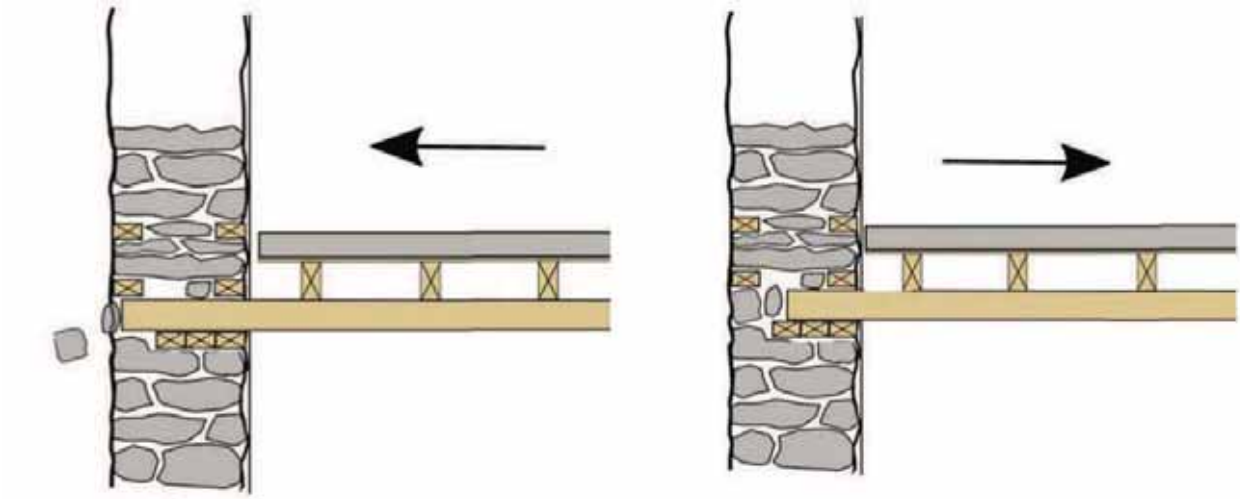
allows the beam’s hohrizontal displacement, during an EQ, without “punching” the gable wall.

For this last feature. it is essential to leave an approximatelly 2” gap between the beam and the masonry (on both sides, as well as on the upper face).

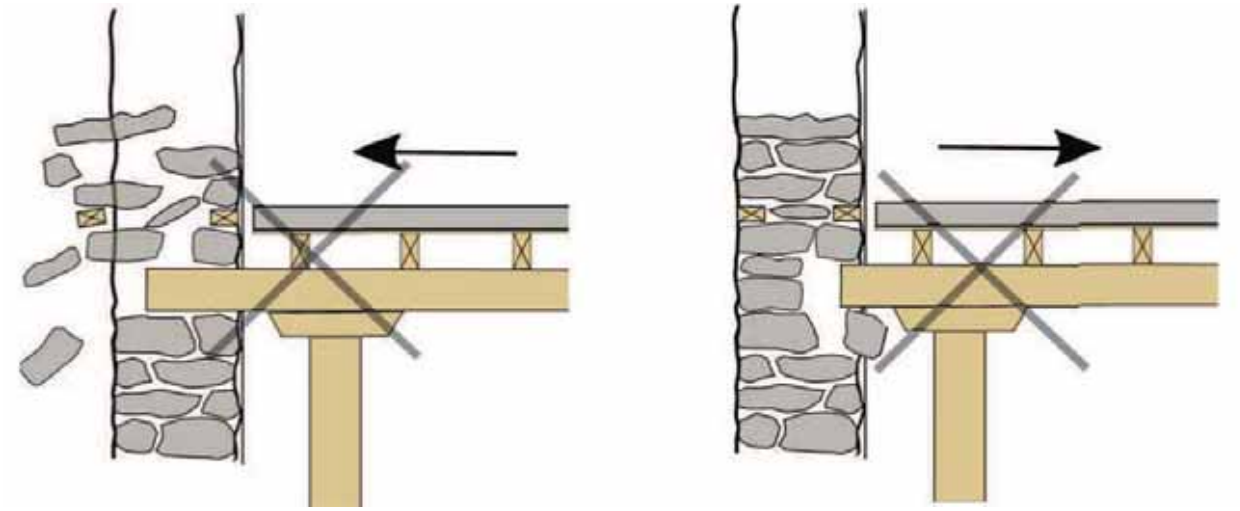
The wooden element upon which the beam will rest will work as a “sliding platform”, keeping the gable wall from beeing “punched” in and out by the beams horizontal displacement.

Stability: The wooden beam (with the weight of the floor) contributes to confining the stone wall, and the wooden planks allow even distribution of the load and horizontal displacement of the beam.	Friction: The friction between wood elements allows the dissipation of energy.

The beam should go in about 3/4 of the wall's thickness, to prevent from coming out, with the inward horizontal movements.
The remaining 1/4 should be filled with stone masonry. It is very likely that the outward horizontal movements will cause the falling of these few stones, but this would not jeoperdize the stability of the wall.



If, on the other hand, the beam is confined in the stone masonry, its horizontal displacement may cause heavy damage to the masonry and even cause collapsing of the upper part of the wall.



The same principle is valid for the floor joists, that should be set on the wooden seismic band, thus distributing the load throughout the walls and allowing inward/outward horizontal displacements without damaging the walls.

LESSON PLAN

WALLS

Wooden posts and beams

4-11

Session duration: theotie 30 mn; practice with stone massonry

Objectives:
In order to help trainees to improve on their actual building habits, the trainer will help the trainees to understand the interaction between the wooden structure and the walls massonry. Help the trainees to understand the stability limit of the wooden structure and how to improve its stability without reducing its flexibility.

Method:
Discussion about the behaviour of the wooden structure under earthquake movement. Ask trainees to identify problems and to develop their own solutions. Synthesis by the trainer who will make available potantial improvment if they have not been find by the trainees themselves.

Trainer team	Session	Pedagogical support :	Tools :
Lecture One trainer for 7 participant Practice One trainer for three group of 7 trainees on practice	Preparatory work : It could be good to produce small scale models to illustrate the different risks taht are related to this wooden structure, and how to reduce these risks. Lecture: Use the model or an existing structure or some drawing to illustrate the way the wooden structure is commonly constructed in the area. Ask the trainees to list the role of each part of the wooden structure and how they interact together. Ask Trainees to give their feeling on how this structure will move under seismic movement and the different damage this structure can face during them. List the different risk and complete them if trainees do not cover everything. For each risk, ask trainees to develop their solution. Synthetise trainees ideas and add some more solutions if required.	Demonstration: Trainer guide: Small model of the wooden structure	

Planning

Before the session:

Lecture

After lecture

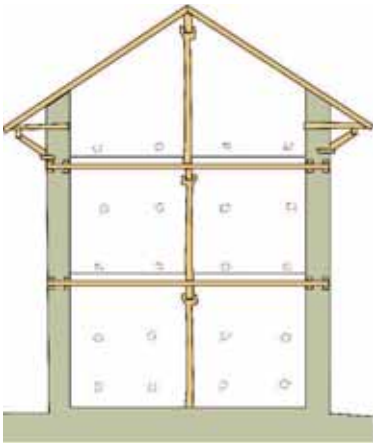
Two complementary structures:

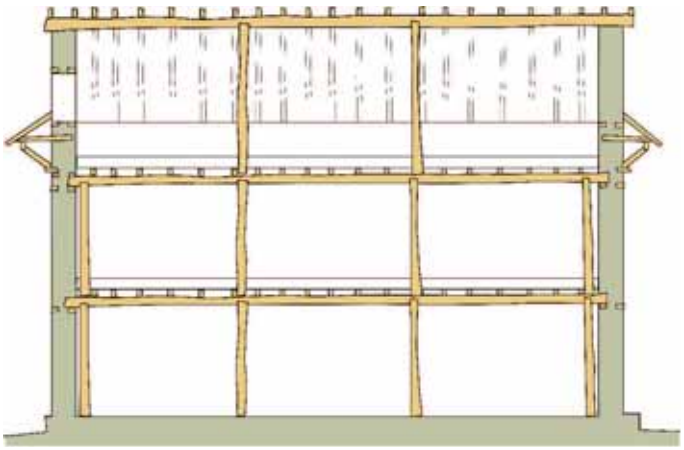
A local common practice is to use a double structure : periferical load bearing masonry walls and wooden structure.

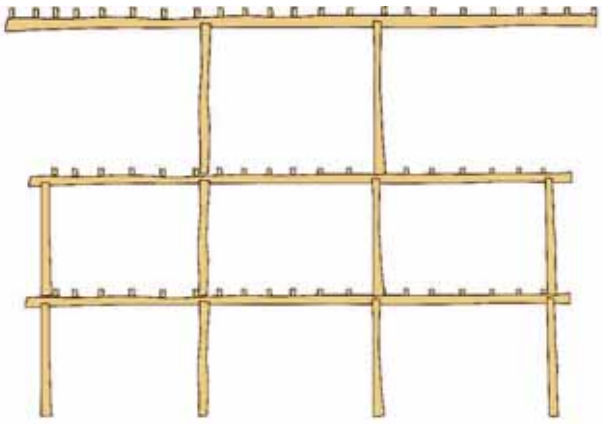
In case of big damages, the second structure avoids the roof and floors from collapsing.

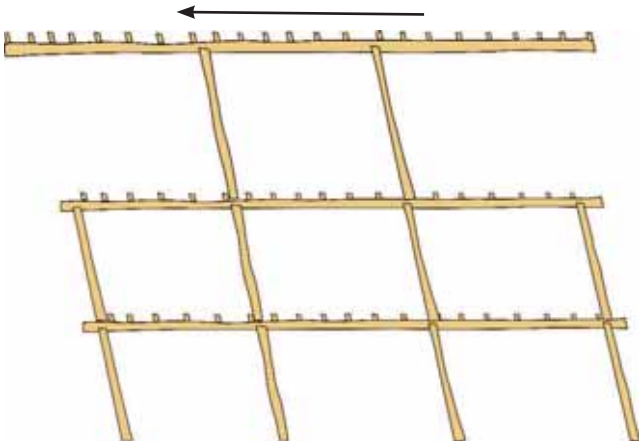
This can give more time to people for going out from the house in case of a major seism, as the floors stand still even if part of the walls collapse.

The wooden structure alone has some weakness against seismic loads because it is not braced. Therefore, it can not stand lateral load which occurs during earthquakes.



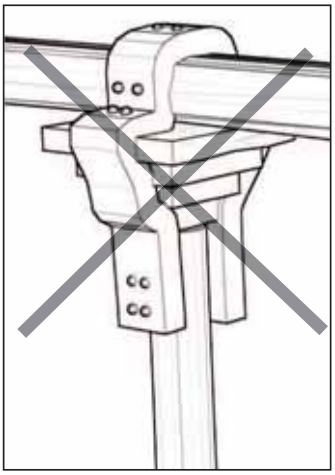


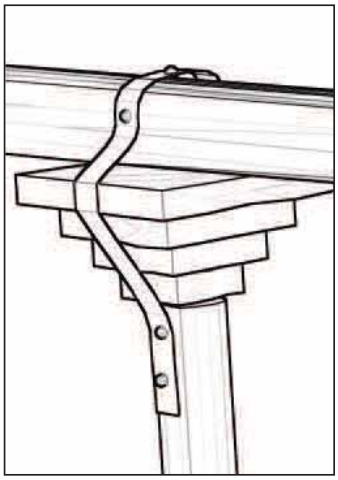




The beam is set on a piece of hard wood that allows it to come back in place in case of moves.

The beam can be fixed to the posts with barbed wires, nails or iron hoop, but the link must not be too rigid.





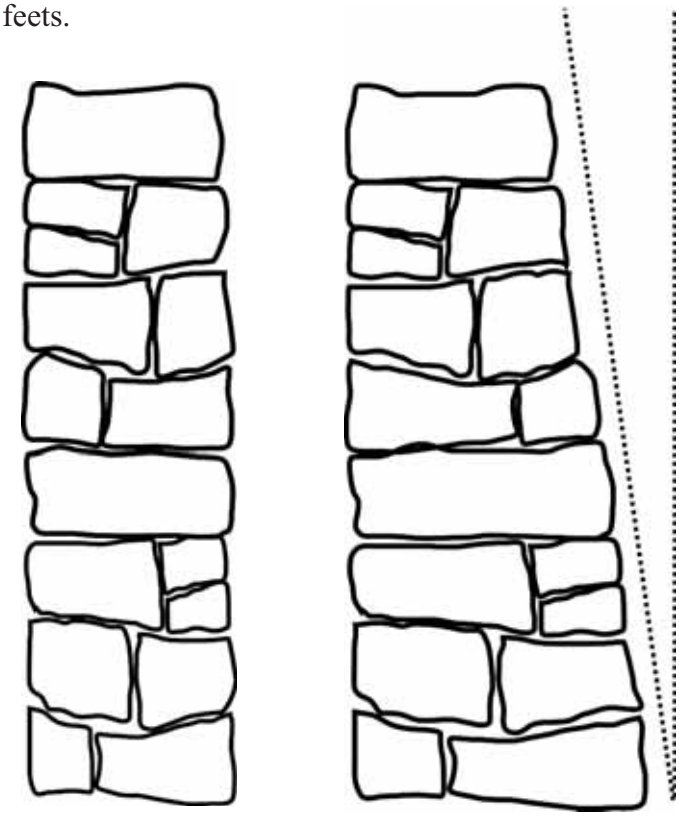
Stability: It is more difficult for the beam to fall from the posts and loose its functions.	Friction: The friction between the support and the beam dissipates energy. The deformation of the links absorbs some energy, through the friction between nails and wood and/or the deformation of iron hoops.

Buttress

The buttress is added to the wall's thickness: the top of a wall with a buttress must remain as thick as the top of a wall without buttress.

The maximum thickness/height ratio for a stone wall should be 1:8 (as recommended in the Building Code). *ex.: a wall 7'high should be around 10"thick at the top*

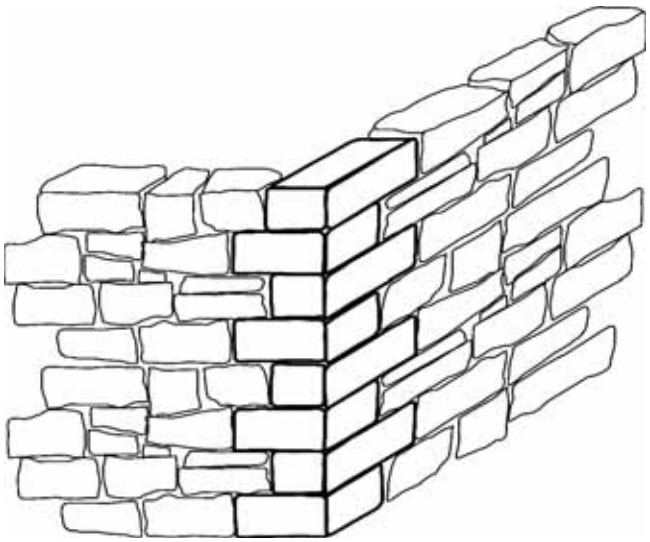
The distance between buttresses should be less than 10 feets.



Stability:
The buttress decreases the thickness/height ratio of the wall without increasing the weight of the upper part. The smaller the slenderness, the greater the stability.

MELA SCHOOL in Anaikot, Kavre - Oct 2012 / April 2013
(by MEEM ARCHITECTURE and NAMASTE NEPAL/DCWC)
photos : http://openarchitecturenetwork.org

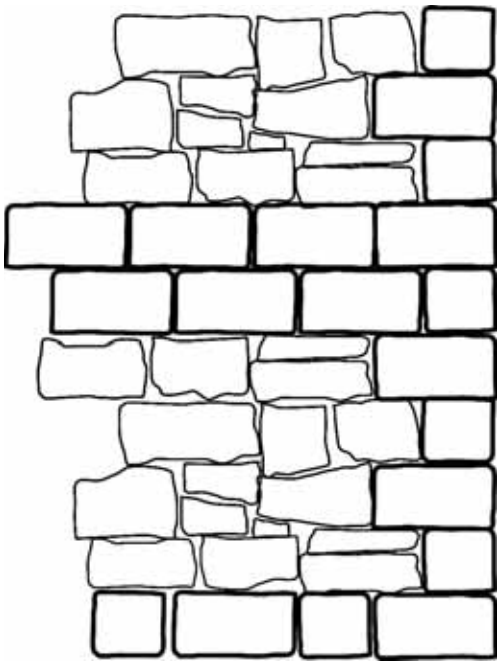
It is quite rare that stones with a proper shape for corners can be found in a “natural” state.
It is, therefore, very often necessary to cut or carve some selected available stones, in order to obtain that proper shape required for the essential structural role that corner stones play.



As an option, corner stones can be replaced by reinforced concrete blocks made on the site.
It is very important, though, that these blocks are of good quality, with resistance and durability standards leveled with the rest of the wall elements (stones), so that this heterogeneous result does not originate different behaviours in the whole wall.

Stability:	Friction:
The good connections between carved stones improve the stability of the corners, and therefore of the whole building.	The contact surface between carved stones is higher than between rough stones, increasing the friction.

According to many factors - including the type of stones available and the labour demands for their cutting/ carving - these stones can be used only for the corners, as well as for corners and some layers.



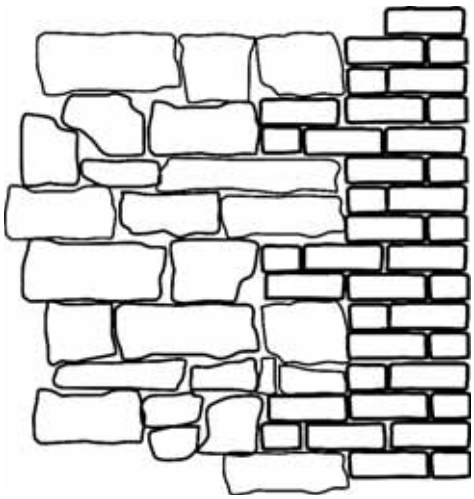
Ultimately, the whole wall can be made with carved stones.

When so, the contact surfaces between them is optimised, and thus also optimising the friction/dissipation.

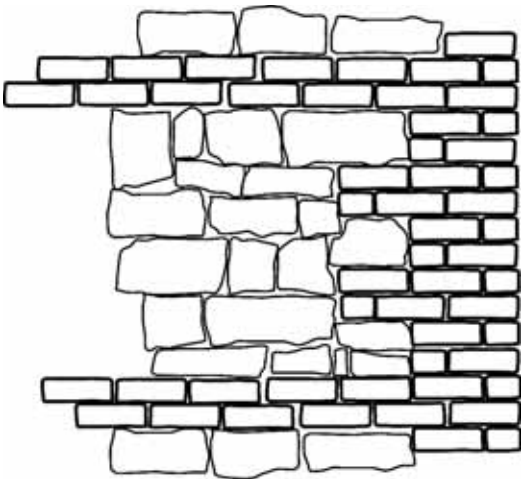
This option requires for a lot of good stones available and a bigger amount of labour.

Stability: The good connections between carved stones improve the stability of the walls.	Friction: The contact surface between carved stones is higher than between rough stones, increasing the friction.

The same principle can be applied using fired bricks in the corners.

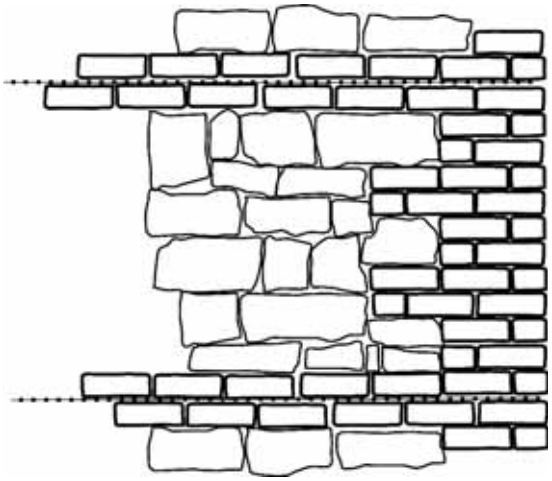


Eventually, bricks can also be used for some layers, that will work under the principle of dissipation of seismic bands.



These brick layers can be reinforced with a wire mesh.

This mesh brings some confinement and some ductility to the wall, improving shearing stress resistance, and the mesh layers maintain the walls together, even in case of cracks or partial collapse.



Stability: The strength of the brick masonry increases the corner's stability.	Friction: The friction between bricks is high, allowing good dissipation of energy.

The walls can be reinforced with concrete layers, in which is set a wire mesh.

These concret layers should be 4" thick and can be used only for corner reinforcement ("stiches"), or for the whole wall (seismic bands), for better reinforcement.

As an alternative to concrete, a strong mortar (cement/ sand, without gravel, dosed at 250-350kg/m3) can be used for these layers, with a thickness of around 3". This mortar should be used at a quite dry state, and thus the stone masonry laying can continue immediately after, without the need to wait for the curing period, as with the concrete. This will also go without formwork.

After a first mortar layer of around 1,5" thickness, set the wire mesh (overlapping the parts) and then another 1,5" thick layer of mortar.

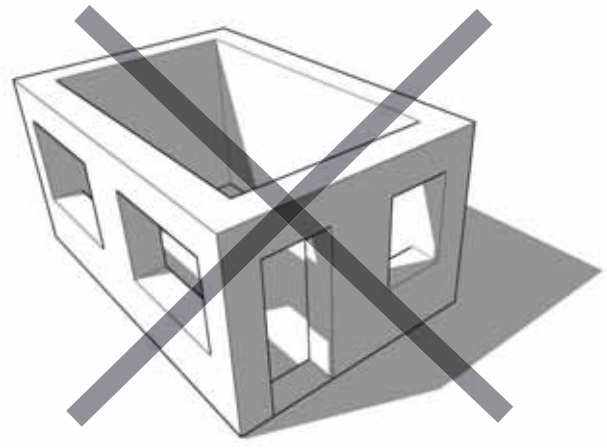
Stability:	Friction:
The wire mesh layers bring some ductility to the wall, specifically in the corners, improving shearing stress resistance, and maintain the walls together, even in case of cracks or partial collapse.	The friction between the stones and the concrete layer dissipates some energy.

Definition

The opening is the empty space left on the masonry of the walls for a door or a window.

Function

The openings permit illumination and ventilation of the inside of the building.
They represent nevertheless a weak point in the structure of the building - it is often from the openings that many cracks appear, therefore it is necessary to look after their solidity.



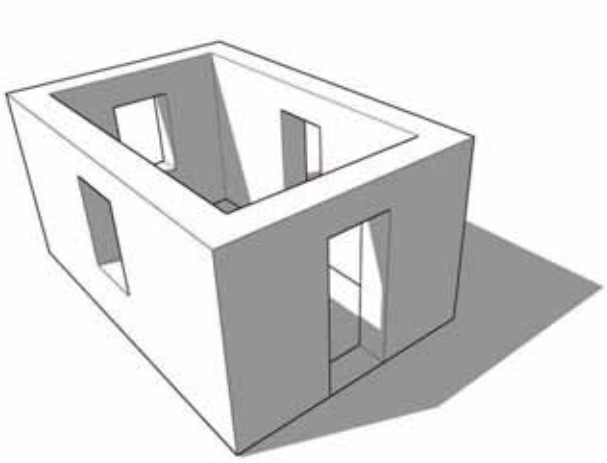
Dimensions

It is strongly recommended to respect some rules in the construction of openings:

- Do not make openings too close one from another (minimum 1m = 3'4");
- Do not place the openings less than 1m from an angle of the building;
- Well anchorage the lintel in the wall, by supporting it on a minimum of 20cm (8") inside the wall, on each side of the opening.

It is strongly recommended to avoid:

- Openings wider than 1.20 meters (4');
- Too many openings on a same wall or openings badly equilibrated in the wall.



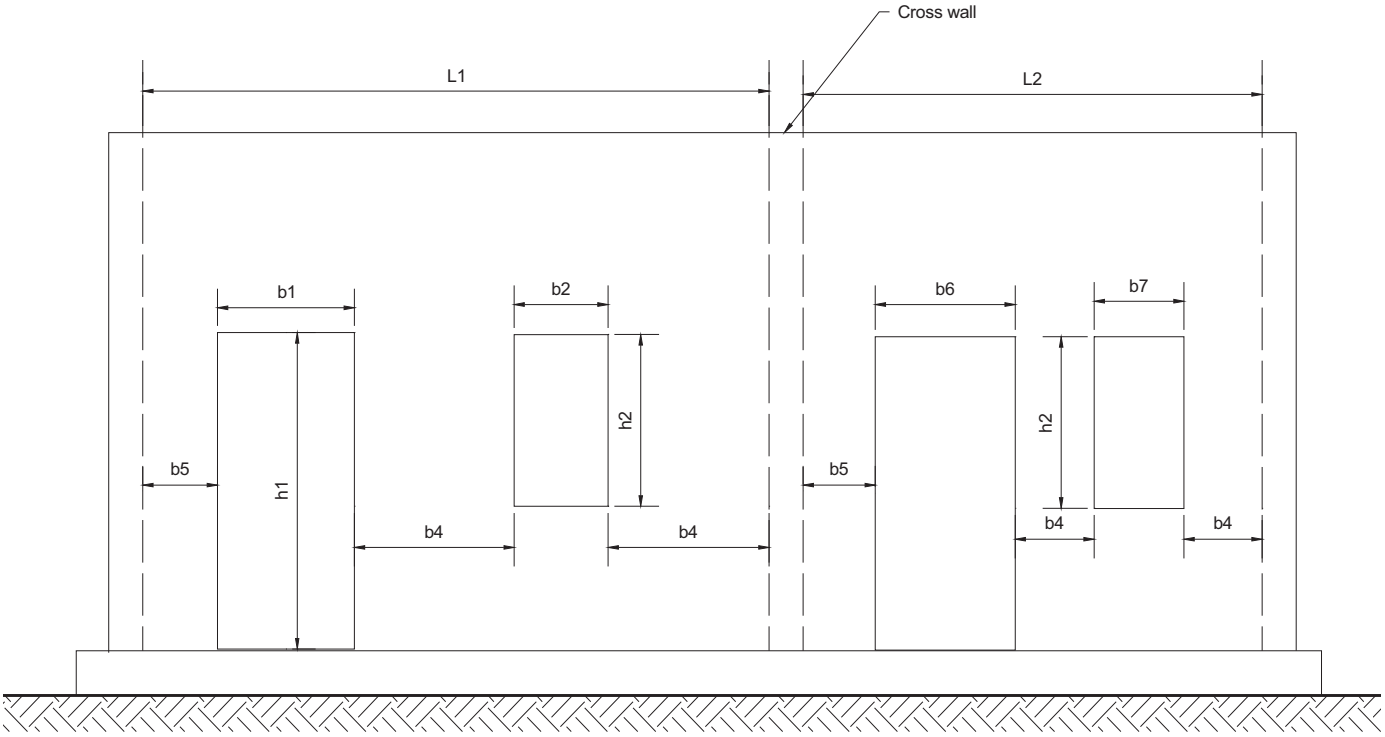
Lintel

The lintel is a horizontal crossbar above an opening, which reports the load of the superior parts on to the lateral points of support.
It is very solicited by the load of masonry it supports and which it transmits toward the sill, and therefore, to avoid cracks, it is necessary to increase the length of its support on the wall.

Openings in Walls

Openings in a wall generally describe those for doors and windows. However, the partial puncture of a wall such as that for a wardrobe, for a built-in closet, or for a Dalan covered verandah with walls on three sides, shall also be considered as openings in this guideline.

Unbalanced openings contribute to the increased vulnerability of buildings during an earthquake. For buildings to be safer, the size and location of the openings shall be controlled as illustrated



RECOMMENDATION REGARDING OPENINGS IN LOAD BEARING WALLS

NOTE:

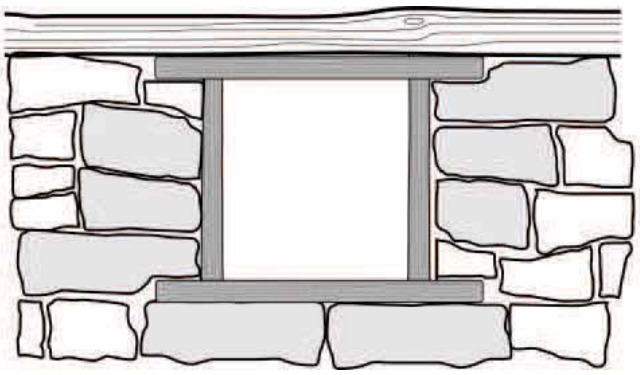
b1 + b2 < 0.3 L1 for one storey, 0.25 L1 for one plus attic storeyed

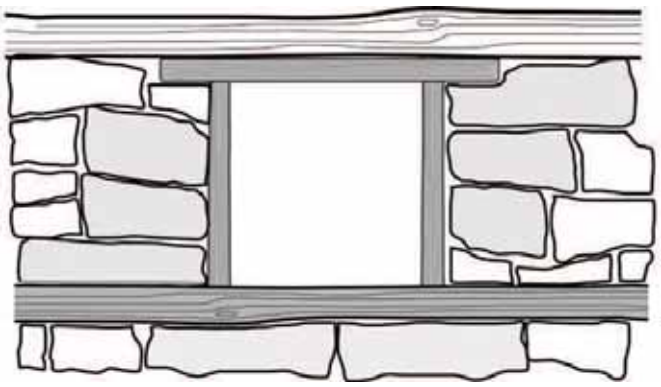
b6 + b7 < 0.3 L2 for one storey, 0.25 L2 for one plus attic storeyed, three storeyed.

b4 ⩾ 0.5 h2 but not less than 600 mm.

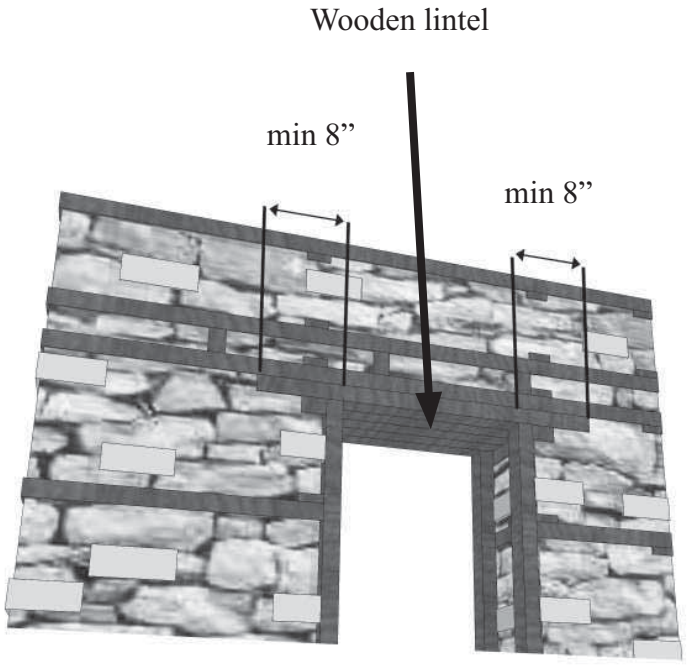
b5 ⩾ 0.25 h1 but not less than 450 mm.

Illustration & text: recommandations from NBC 203





The borders of the opening must be treated as a corner of the building, with the most regular through stones. An horizontal wooden band at sill level can act as the window sill.



Door and window lintels should be installed inside the walls with a minimum end bearing of 20cm (8”). Traditionally, in the three districts (Dolakha, Ramechhap and Sindhuli), windows and doors don’t have wooden side boards. Instead, a double framing system is used.

Stability: The wooden border of the window prevents the stones from the masonry to fall.	Friction: The friction between the wooden border and the stones can dissipate energy.

LESSON PLAN

ROOF

Definitions and principles

7-1

Session duration: theotie 30 mn; practice with stone massonry

Objectives:
In order to help trainees to improve on their actual building habits, the trainer will help the trainees to understand the behaviour of the roof and its different part under seismic movement. Help the trainees to understand the stability limit of the roof structure and how to improve its stability without reducing its flexibility. Specila focus will be done on maintenance (degradation of some struictural component) and risk link to the increasment of the roof load along the years.

Method:
Discussion about the behaviour of the wooden structure under earthquake movement. Ask trainees to identify problems and to develop their own solutions. Synthesis by the trainer who will make available potantial improvment if they have not been find by the trainees themselves.

Trainer team	Session	Pedagogical support :	Tools :
Lecture One trainer for 7 participant Practice One trainer for three group of 7 trainees on practice	Preparatory work : It could be good to produce small scale models to illustrate the different risks related to this roof structure, and how to reduce these risks. Lecture: Use the model or an existing structure or some drawing to illustrate the way the roof structure is commonly constructed in the area. Ask the trainees to list the role of each part of the roof structure and how they interact together. Ask Trainees to give their feeling on how this structure will move under seismic movement, how it will interact with the walls it is lasting on, Ask the trainees to list the different damage this structure can face during earthquake. List the different risk and complete them if trainees do not cover everything. For each risk, ask trainees to develop their solution. Synthetise trainees ideas and add some more solutions if required. Emphasis in the risk related to maintenance: Ø Rooting of some wood Ø Adding new layer of mud every year on top of the wall (for waterproofing) that results in increasing the load of this roof . Give trainees advices to redo the roof waterproofing at least every ten years (remove the mud, replace the spoiled peices of wood, redo the whole things).	Demonstration: Trainer guide: Small model of the roof structure	

Planning

Before the session:

Lecture

After lecture

Protection

The roof protects the building itself and its occupants from the rain, the snow and the sun.

Thermal

The roof provides insulation to the building. An important part (around 30%) of the thermal losses happens through the roof. Its good insulation is therefore important. Thatch roofs provide a very good thermal insulation, as well as an hygrometric regulation through ventilation.
Slates are good enough, but CGI sheets do not protect from the heat nor from the cold.

Aesthetic

The form and look of the roof is of first importance for the general aesthetic of the building.

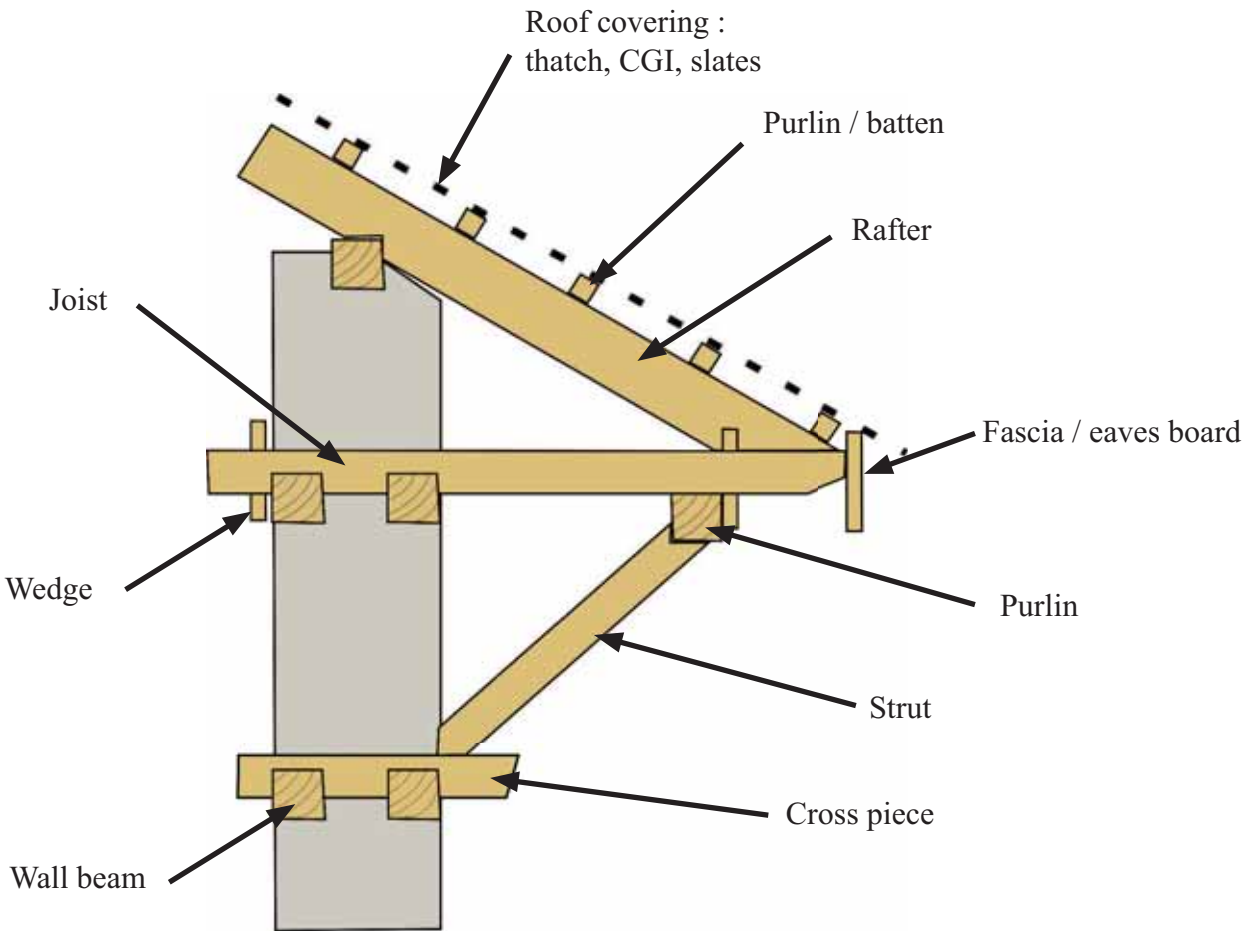
Seismic risks

A light material for roofing is less dangerous : CGI sheet and thatch. Slates should be very well tied to the roof structure.

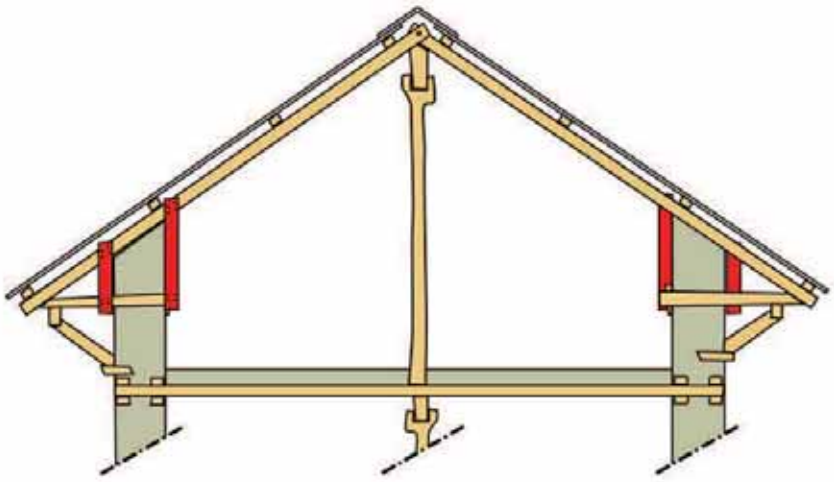
NB : Thatch roofs present the best combination of surety and thermal confort.

Something that could help reducing the problem metioned above - regarding CGI non-insulation - would be the use of a bamboo or wooden (planks/boards/plywood) layer under the CGI. This would provide some insulation, but would specially restrain thermal transmission by radiation, in both directions - both inwards (overheating) as outwards (overcooling).
To enhance this, a mud layer can also be added, between the bamboo/wooden layer and the CGI, as traditionally used in these regions for fired clay tiles roofs.

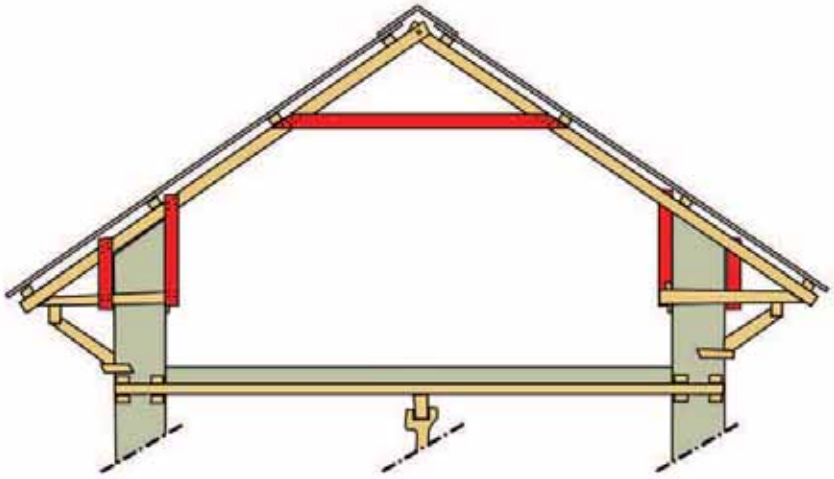
The rafters are commonly supported by struts, which avoids inducing too much horizontal stress on the top of the walls.



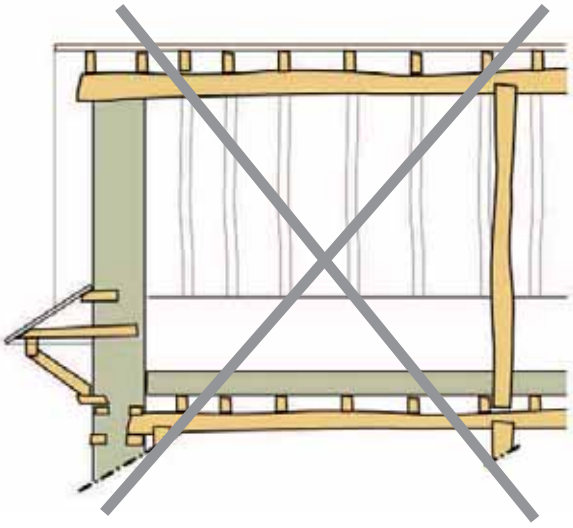
Vertical wooden elements can be added to connect the rafters to the horizontal joists in order to better tie the roof down.

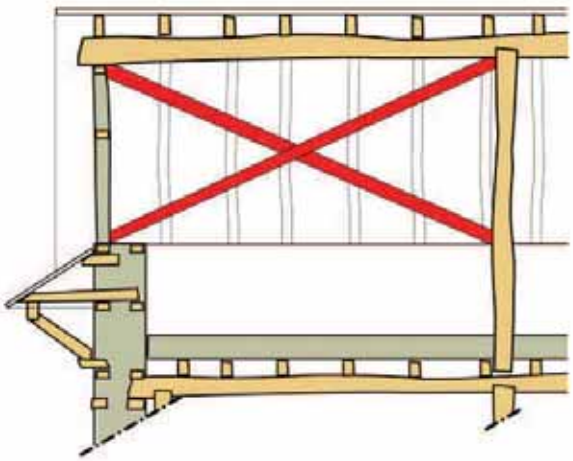


In order to reduice the amount of timbers for the reconstruction, the post and the ridge beam can be replaced by using a truss system with double collar ties. This solution requires good connection between the wooden elements and can be considered depending on the use and the size of the attic.
This option is appropriate for light covering materials (CGI sheets) and low exposure to snow loads.



To prevent the collapse of the gable walls, it is recommanded to build light gable walls which are properly braced and confined.





Light gable walls can be made as follows :

“Wattle and Daub”

a bamboo strips (or tree branches) mesh, attached to a wooden frame, set between the rafters, and plastered with mud on both sides.
An outside layer made out of lime increases the resistance of the surface to weather solicitations.

Partition stone masonry

subdivision of the gable wall with bracing boards into smaller partitions, filled with flat-stone masonry, 4” thick.
Round stones should be avoided, as they will fall out quickly.
In order to improve the friction between wood and masonry infill, nails should be added before the infill. Joints made out of lime mortar increases the resistance of the surface to weather solicitations.

Confined stone masonry

stone and mud mortar masonry, with a maximum thickness of 10”, that becomes properly confined by the rafters and additional wooden elements, such as a window frame.
Flat stones should be preferred, laying them perpendicularly to the gable wall.

Thermal

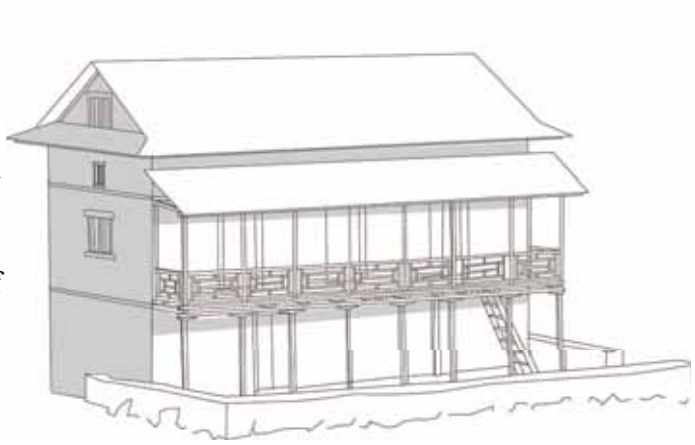
The veranda protects the southern facade from the direct sun, reducing the heat during summer.

Cultural

The veranda is one of the typical elements of vernacular architecture of this region. Most of the houses have one.

Social

The veranda is a half public half private space. It is an outside place but protected from the sun and the rain, and many social and household activities are held there and are strictly connected to this particular element of the house.



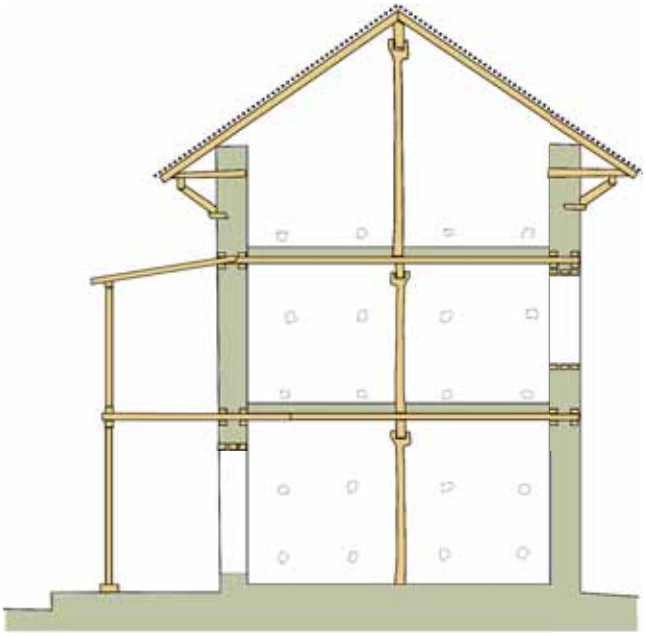
Illustrations (2 types of “verandas”) :
in Dolakha wooden structure “plugged to the main façade” (up);
in Ramechhap, the outter space is integrated in the general volume (down).

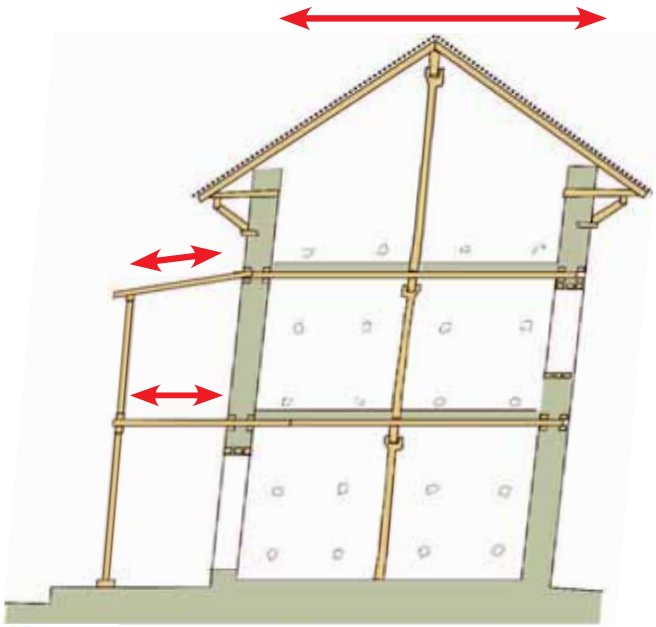
NB: in Sindhuli, both types can be found.

The veranda works as a flexible independent structure "plugged" to the main masonry structure.

In case of an earthquake, the light wood/bamboo structure and the heavy stone walls won't move in the same way.
The link between these two elements should then be flexible.

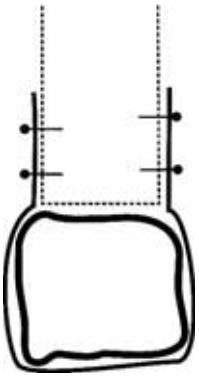
In the local traditional architecture, the beams and rafters can slide horizontally on their support, thanks to a large overlapping.



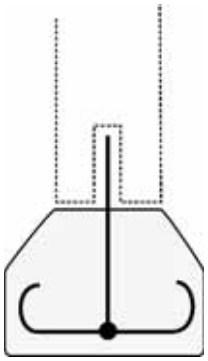


Wooden posts should not be put directly in the ground (specially buried), to keep them from rotting by moisture or insect attack, so they should be set on a footing.

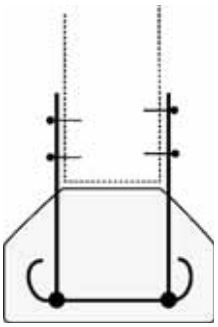
This footing can be made with a stone.
In order to prevent the post from coming out of place, it should be well attached to the support footing. This can be done using a metal strip or some strong wire, fixed to the post and passig around and under the stone.



As an alternative to big stones, the support of the posts can be made with 20x20cm (8”x8”) prefab reinforced concrete blocks, with a steel rod end coming out. This steel rod allows lateral blocking of the wooden post.



Another alternative is a system such as the previous, but instead of a rod end, leaving steel parts coming out of the concrete block, to fix on each side of the post.



The same principle can be applied using torsade wire.

Stability: The wooden posts may move slightly but cannot come out from their support.	Friction: The friction between the post and the basement allows some dissipation of energy.

Definition

The slab is a large surface of hard material used as floor, cover, or artificial soil.

Function

The slab allows an even distribution of the load (building + people + furniture) to the ground.

The slab is generally made of earth, that can be mixed with coal tar or/and with cow dung.

The floor slab must not act as a diaphragm and must not transmit stress to the walls.

If thick concrete slab is used, a gap of 2 inches between the borders of the slab and the walls is strongly recommended.

Aesthetic

The plaster brings good finish to the wall. According to personal preferences, it can be made more or less flat or polished, giving a more textured or "mortar-like" aspect to the wall.

Protection

Plaster prevents wate (rain/snow) to enter the wall, and thus protects the mortar, the joints and the wall as a whole. It also prevents from animals and insects.

Insulation

The plaster blocks the air circulation, improving the insulation of the building. Nevertheless, mud plasters still allow exchanges that keep air sane on the internal.

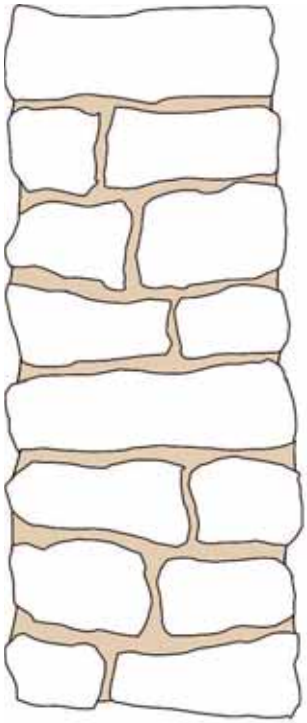
Humidity control

Walls of stone and mud mortar must have plasters made out of mud or lime, in order to allow the drying of the wall. If necesary, lime mortar can be mix with low proportions of cement (max. 5% vol).

If no plasters are applied on the outside (very often in Dolakha, for exemple), there should be a joints maintenance, in case of erosion. This regular procedure should prevent rainwater from entering deep inside the stone masonry wall.

If the mud mortar is wet, the wall resistance decreases.

INSIDE



OUTSIDE

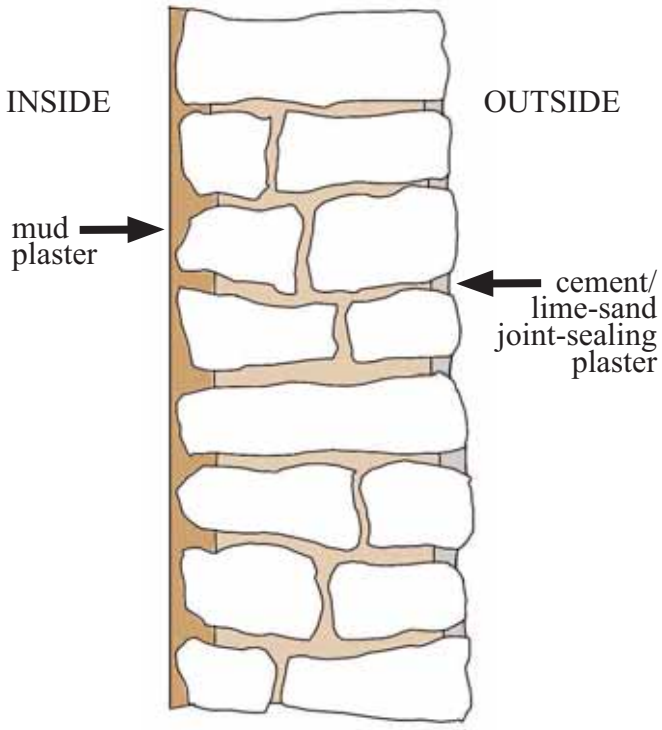
OUTSIDE

Stability: By filling the gaps between the stones, the plaster can prevent them to fall and slightly increase the stability of the wall.	Friction: The breakage of the plaster can dissipate energy.	Maintenance: The plaster helps maintaining the wall and reduces overall maintenance needs.

To protect the stone and mud masonry wall, external joints can be filled with a cement-lime-sand plaster (1vol. cement + 3 vol. lime + 1 vol. sand).

The inside face of he wall is not affected by rain / snow / wind, so it can be plastered with mud mortar.

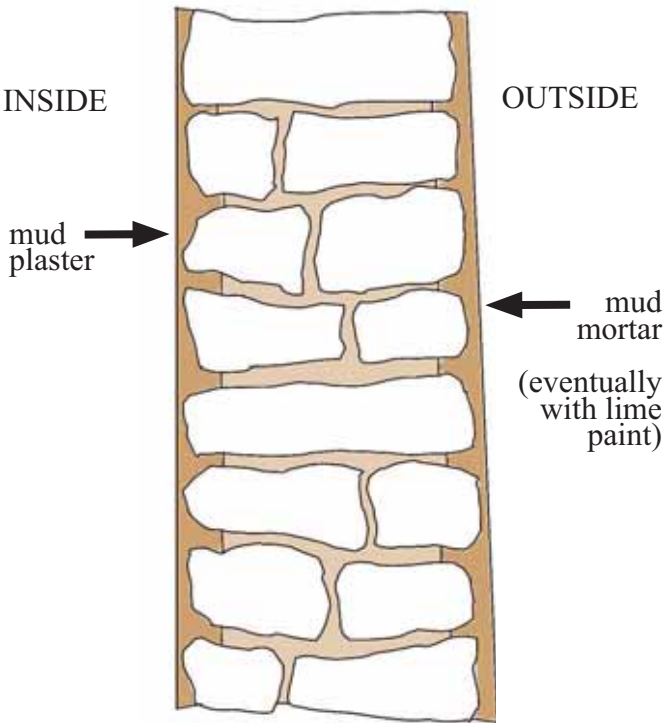
OUTSIDE



Outside face can also be plaster with mud mortar.
When affected by the weather, it has to be repaired.

Mud plaster can be painted with lime based paint to improve its lasting. This can be applied regulary. It can also be coloured with clay or other natural pigments.

OUTSIDE



Stability:	Friction:	Maintenance:
By filling the gaps between the stones, plaster prevents them to fall and increases the wall's stability.	The breakage of the plaster can dissipate energy	The plaster helps maintaining the wall and reduces the maintaining needs.

General considerations

It is necessary to clear the site before any construction:

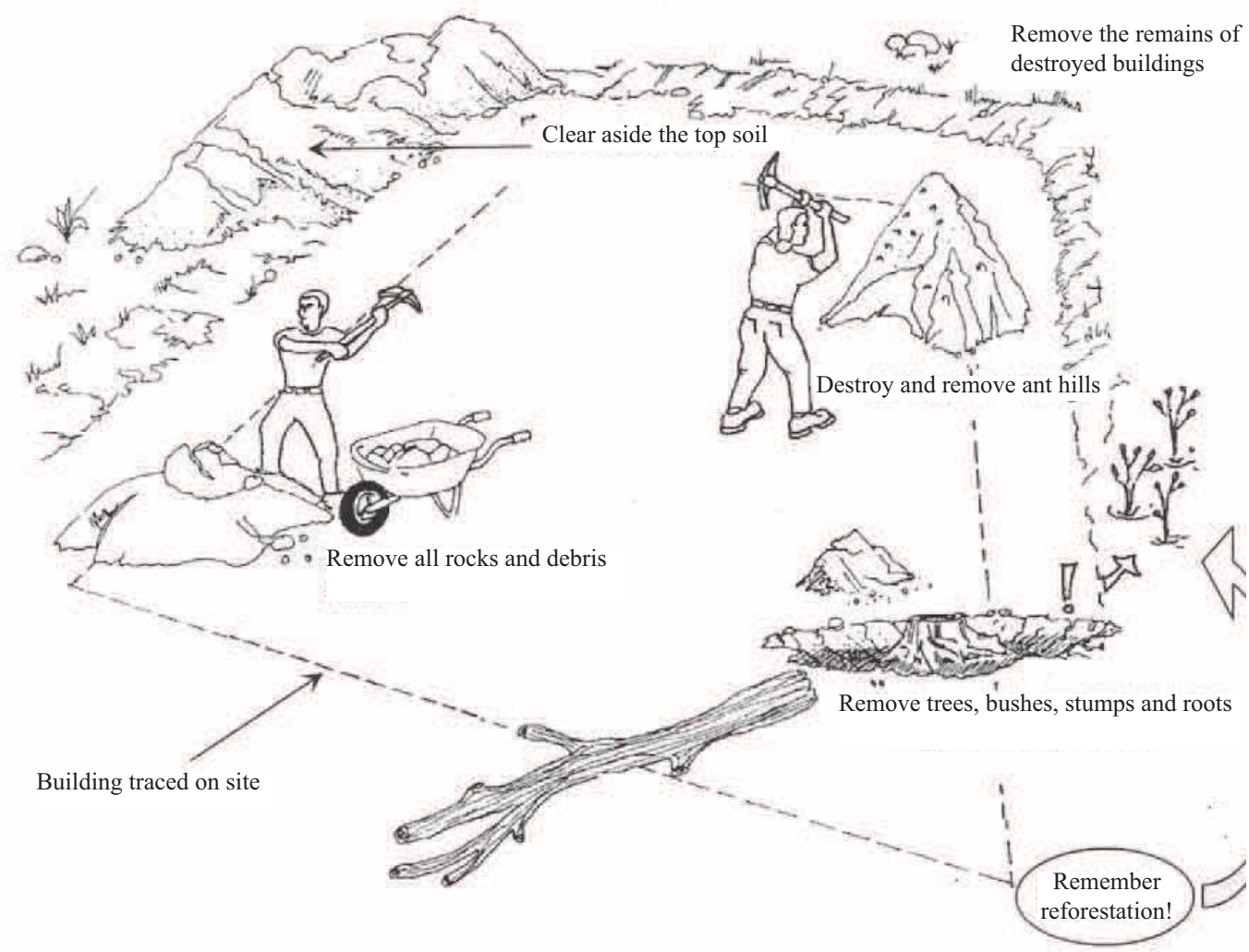
Vegetable top soil should be removed up on the whole surface of the building's - it assists to set the building on a good and firm soil.
That top soil, consisting of vegetable matter, can only be used for agricultural purposes and not for construction.
Remember to remove stones, stumps and roots, since the presence of organic materials on the site of the building would encourage the presence of insects and rodents.
An extra allowance of about 2 meters (6 feet) should be given all over the perimeter of the proposed building.

In case of using a site where there was previously a house which has been destroyed, all the remains and debris should be removed.

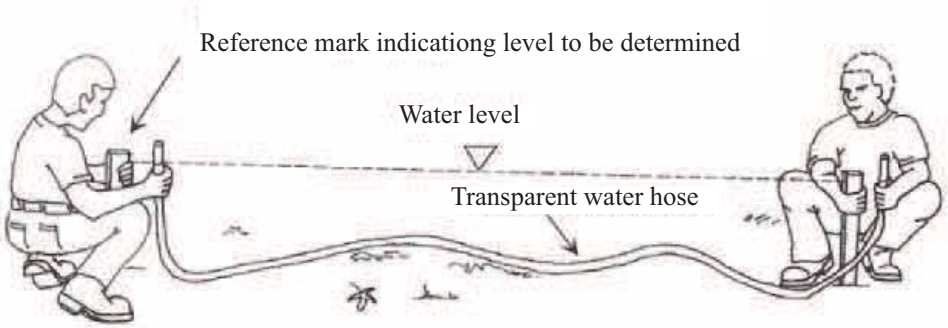
Determine the slope and the levels of the site through locally known techniques : for example, using a water level (hose pipe), boning rod or spirit level.

In the case of the water level, take a transparent hose pipe (with enough length) fill it with water, making sure no bubbles remain, and put each end of the pipe at a different point of the site, turning them upwards, so that water won't come out When the water stabilizes, both ends will be leveled, indicating the lowest and highest of both points. Measure height between water level and ground - be careful: where the water rises up higher from the ground is the lower point of the site.

During this procedure, be careful not to step on the pipe and keep checking for any air bubbles inside it.



Before starting construction, the site must be cleaned and levelled, both to set out the building's position and store material



Once the water is stabilised at reference height, mark on the other side

These two marks provide the horizontal level

It is very easy to transfer the reference height from the first peg to the others by using a transparent hose filled with water

Definition

The setting out of a building is the marking of its position (trenches, width of the walls, pillars, etc.) on the site.

Function

This step is very important and requires a lot of precision in order to avoid further problems when connecting the walls or setting the roofing.
A perfect 90° at the corners, for example, will increase the walls resistance.

Method

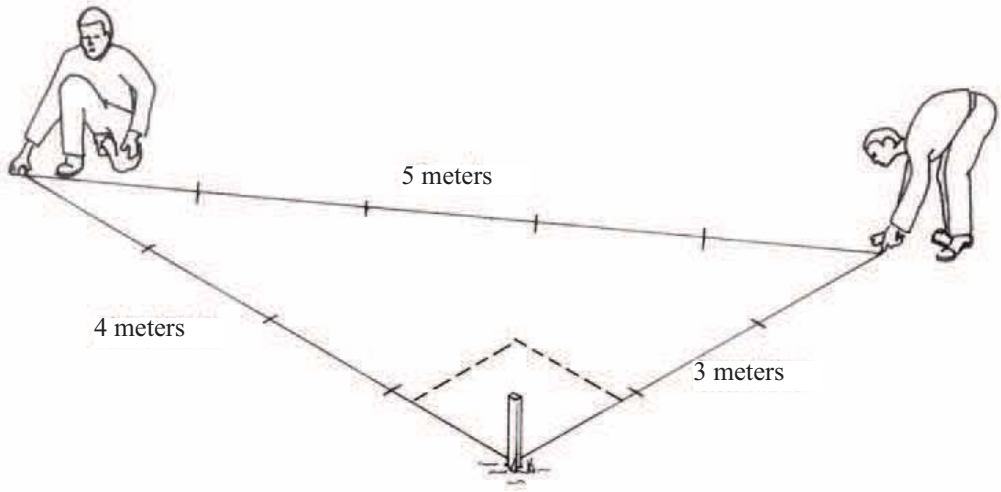
Set out four lines representing the axes of the walls.
Use the "3-4-5" rule for the right angles : put the 0 of the tape on the first peg, and make a triangle with it, whose angles are the numbers 3, 8 and 12 (this one overlaying the 0).

When the 1st corner of building is correct, make the same thing with the 3 other corners.

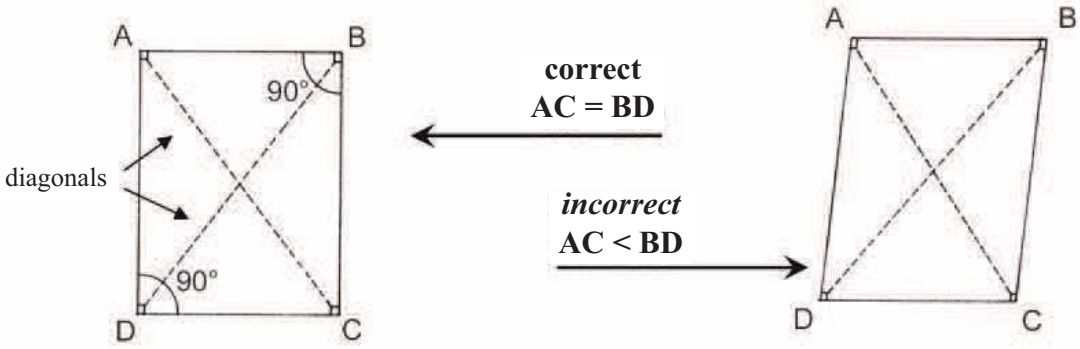
After defining the angles, check the diagonals to make sure they both have the same lenght.

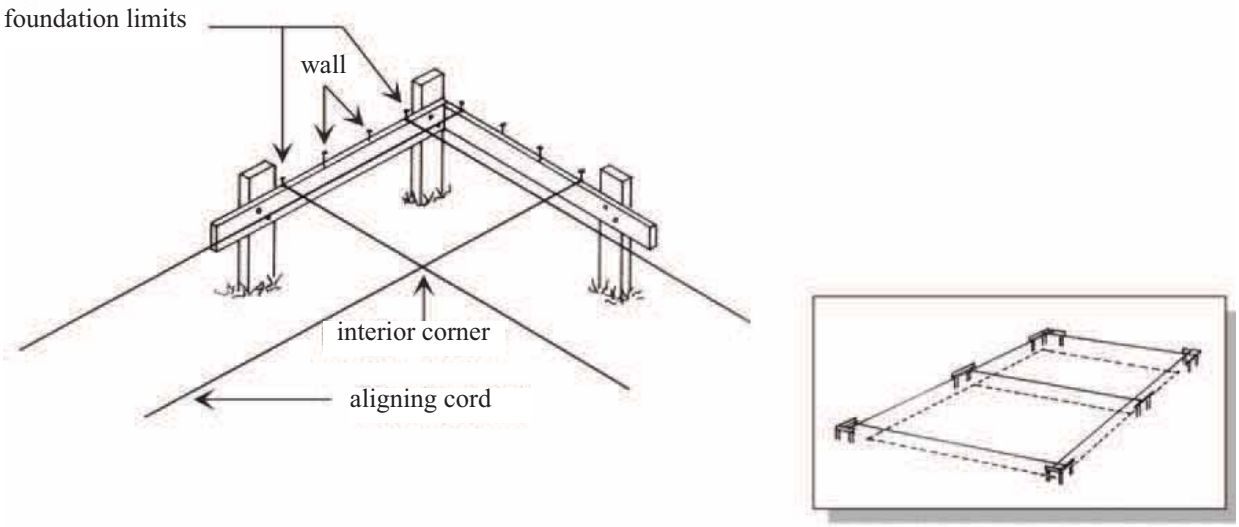
When the angles are correct (90°), extend the lines and fix the pegs far from the actual corner of the building.

Attach four cords to the pegs, representing the axis of each wall. From those, draw the limits of the excavations on the ground : trace them on the soil using a pick-axe or similar tool, or by first dropping chalk or any other visible powder vertically from the cords and then proceeding to mark them with the pick-axe.



After fixing the four corners, check the diagonals
Their lengths must be equal





Definition

The excavation is the hole or trench made in the ground in order to receive the foundations of the building.
The excavations are necessary for all external and internal walls, columns and piers of a building.
Excavation is needed whenever the stone solid ground is not reached during the clearance of the site process.

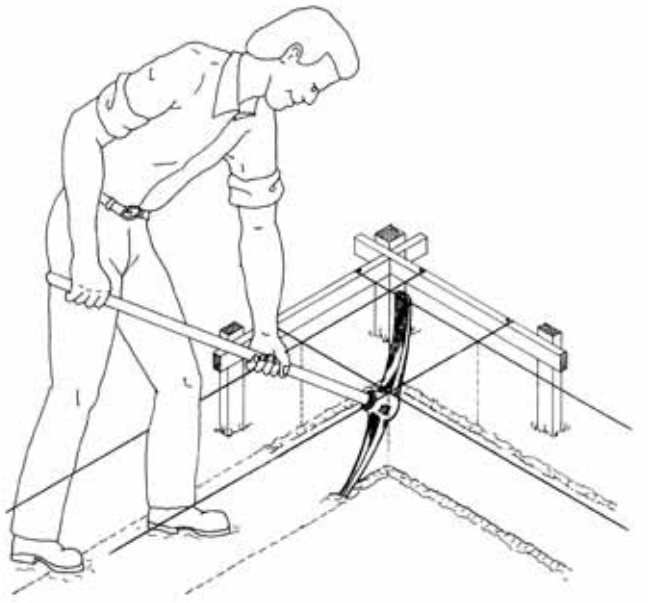
Function

Excavations serve the purpose of receiving the bases of the building on a good soil, a hard soil.

Method

The excavations should always be wider than the thickness of the wall, and deep enough to reach the good soil (soil hard enough not to be easily dug).
Even if that depth depends on the weight of the building, it is always necessary to dig until the pick reaches a hard surface.

Follow the trench limits previously marked and dig vertically, following the alignment given by the cords.
Use straight edge to prepare level surfaces at the bottom of the trenches.
Keeping the bottom of excavations damp and compacting it with a tamper or hammer is a good practice.



Evacuate all the top soil away from the site - eventually stock it, but only for agricultural purposes and not for construction.

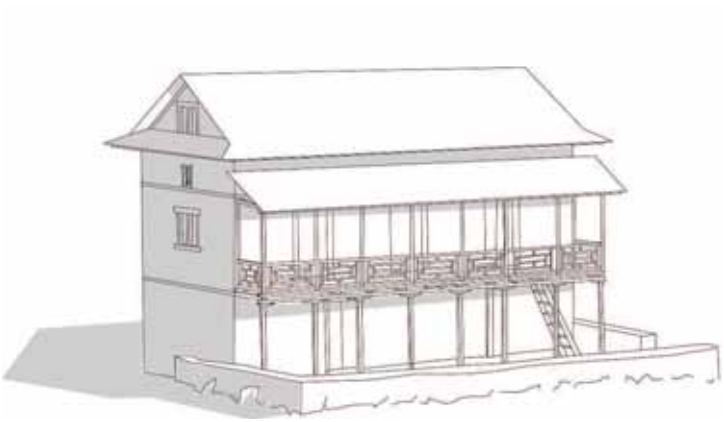
Stock the good soil near the site, for future back filling and drainage works.
Put aside the soil that doesn't contain organic matter and could be used for mortar and/or plaster.

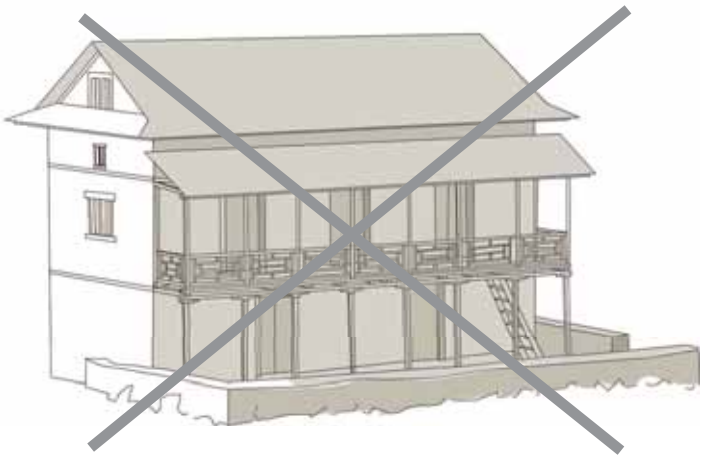
General considerations

Orientation of the building is very important to ensure thermal comfort.

With hot days and cold nights, the best is to accumulate sun heat during the day, for it to be redistributed during the night. The masonry wall inertia represents a big advantage for this.

Direct sunshine is stronger at southern side, therefore, the longest wall of the building should be facing south.

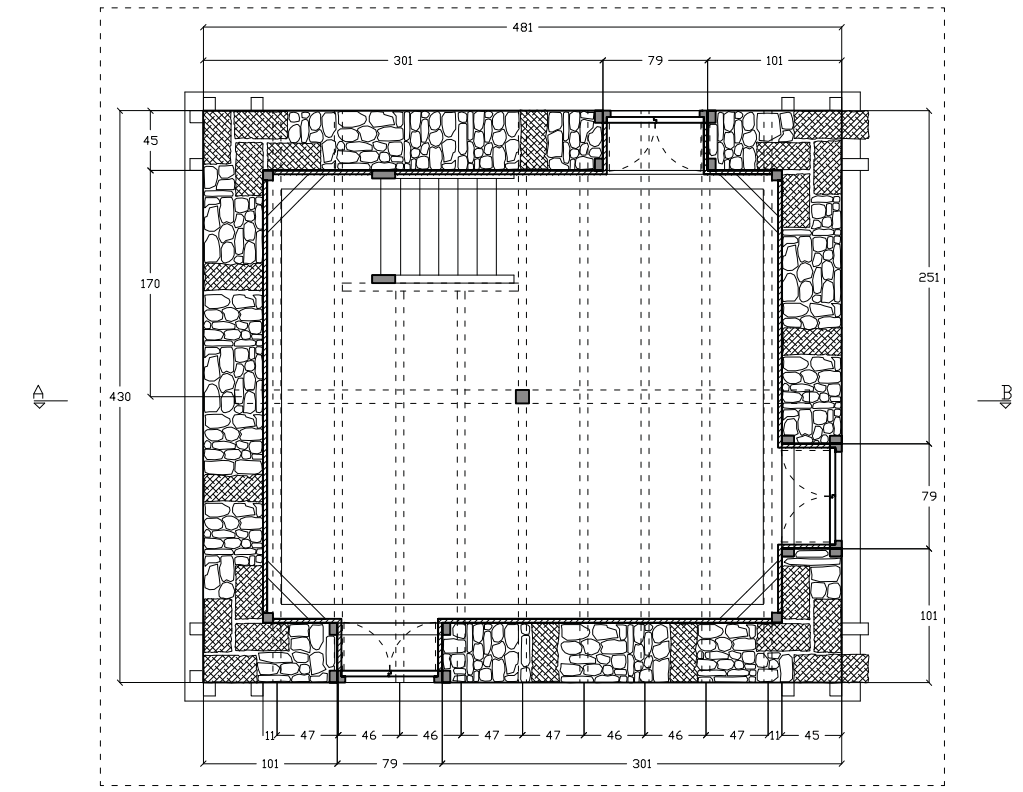


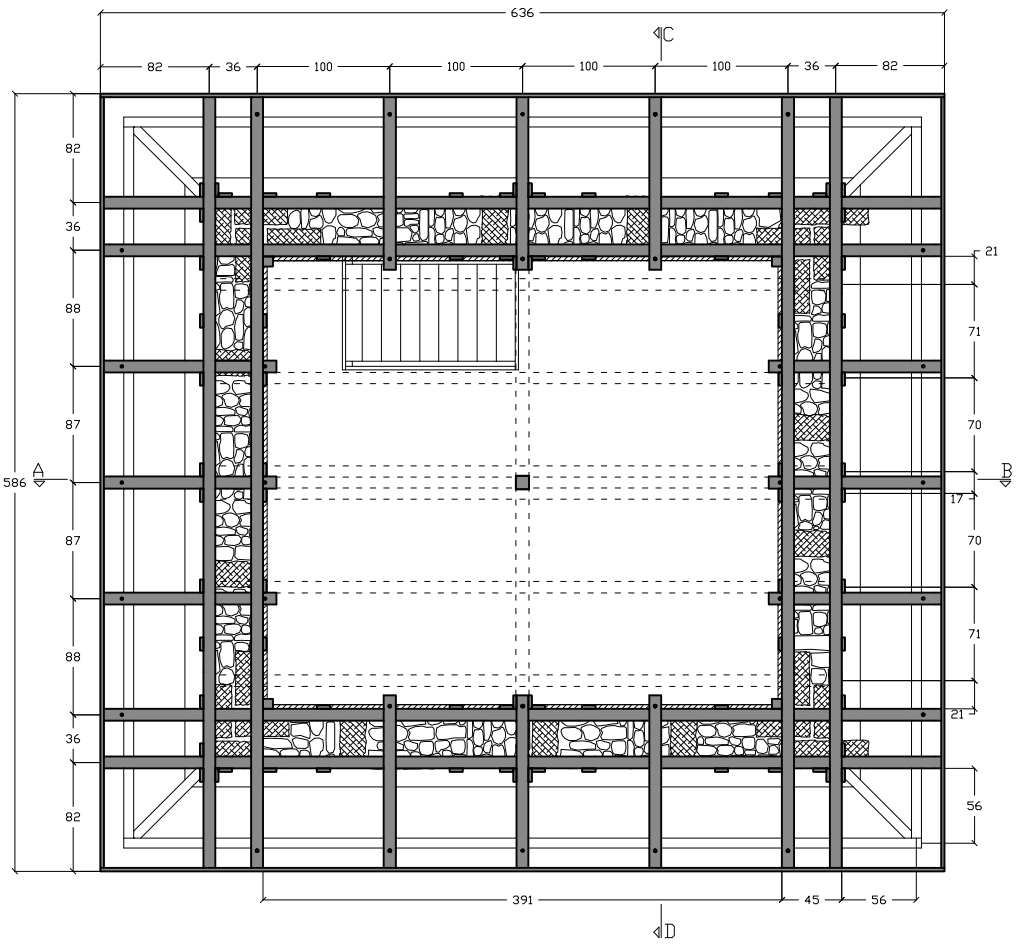


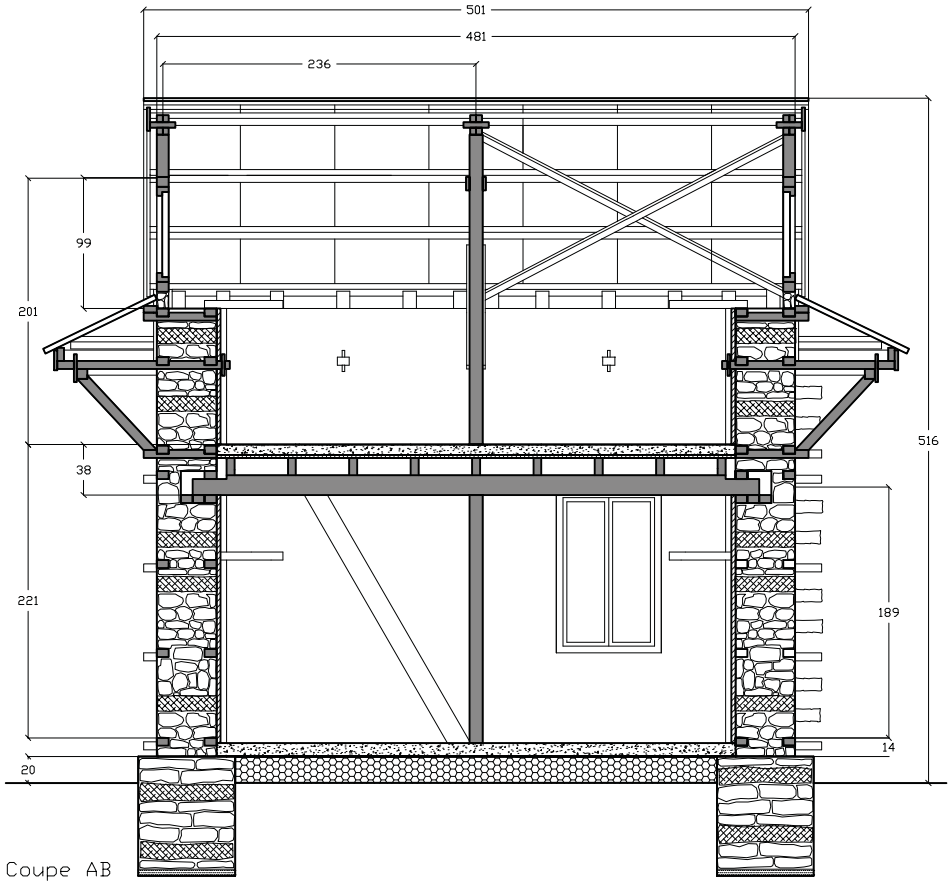
NB : In the mountains, the main orientation of the houses is given by topography.

Lands available are scarce due to agriculture, topography and relief. Houses are usually located along steep contours (the level lines) and sunny slopes, in order to minimize the need for retaining walls and to maximize passive solar energy gains.

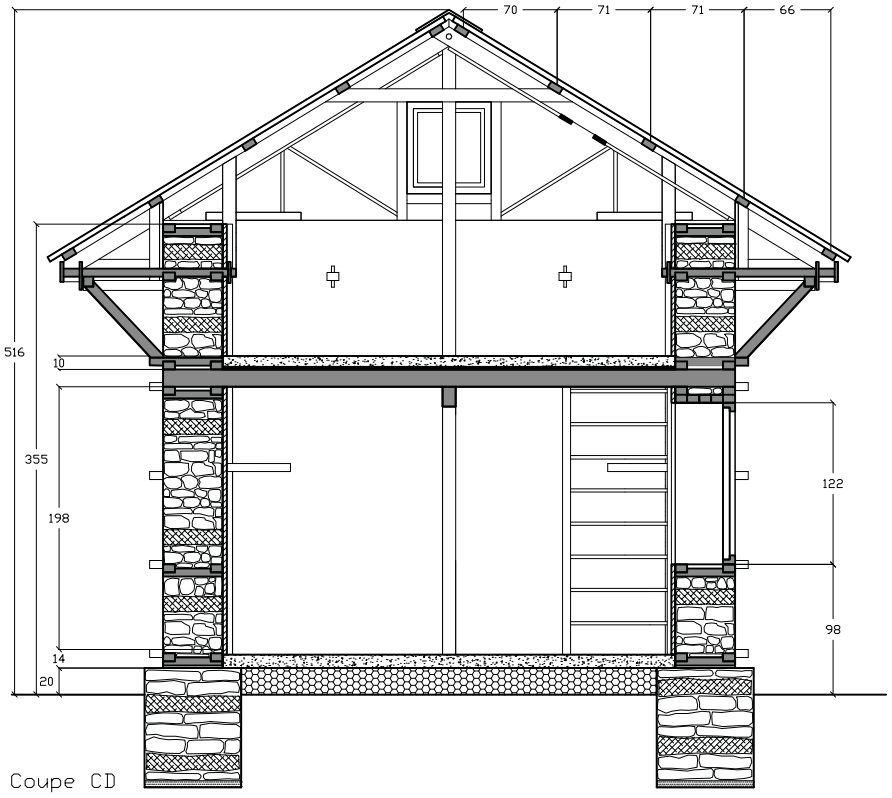
The TDB integrates technical and constructive solutions described in this guide.
It is to be built in several VDC in the three affected districts, with regional and contextual adjustements.



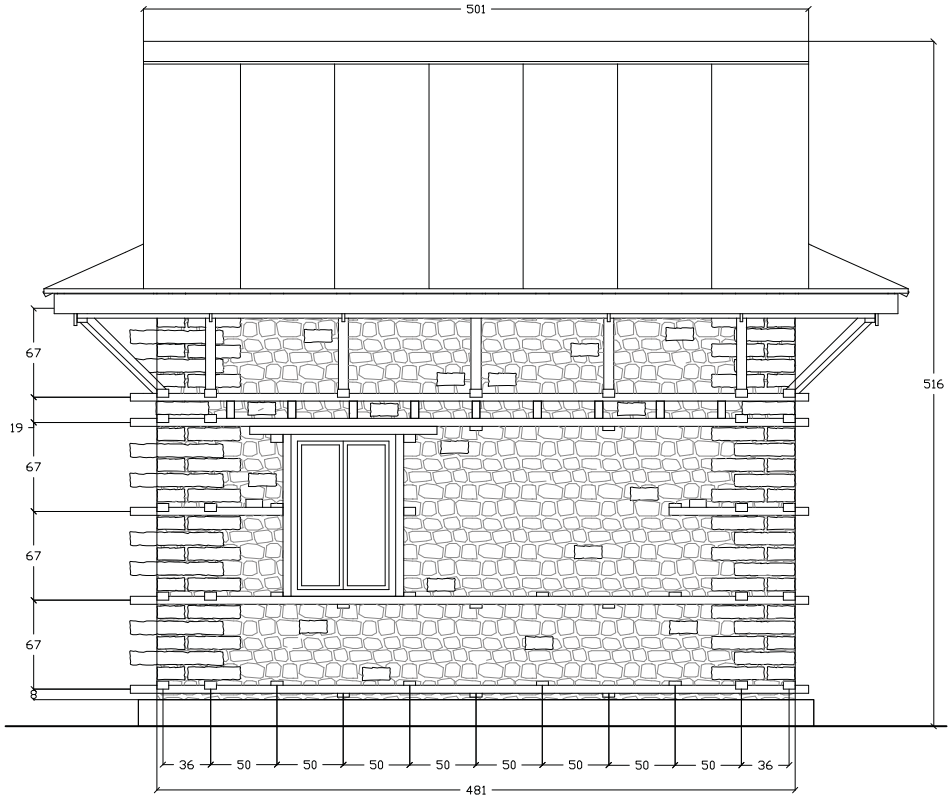




Coupe AB



Coupe CD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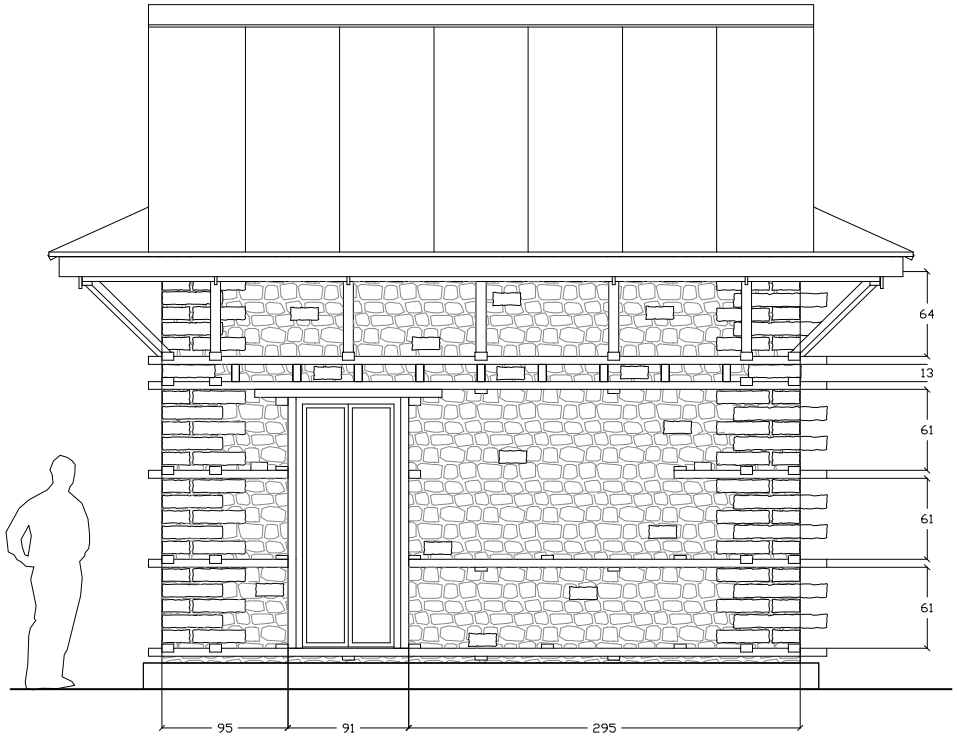
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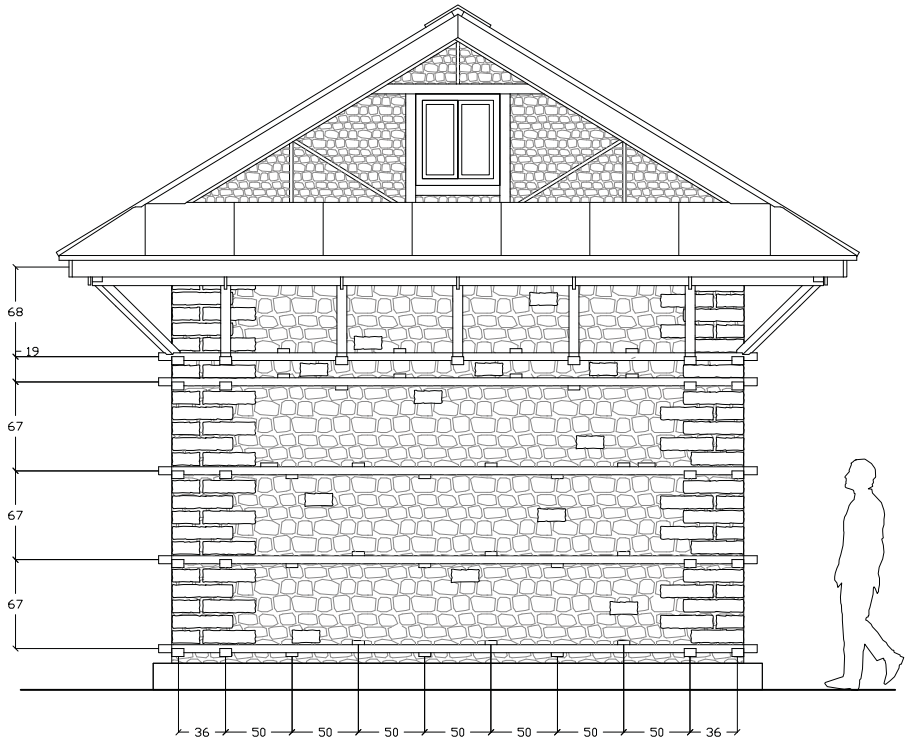
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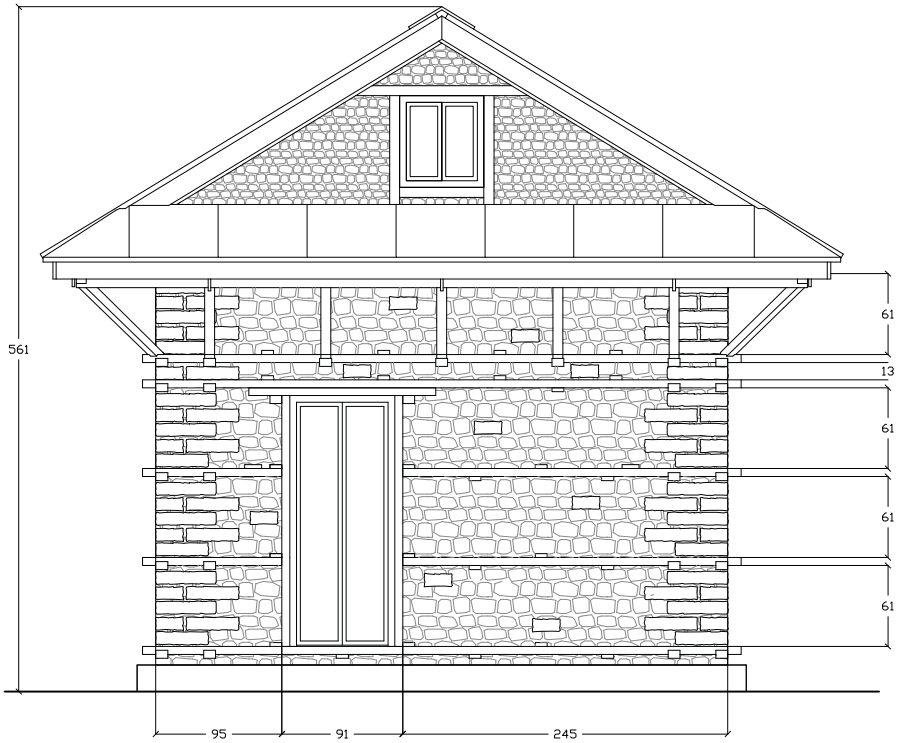
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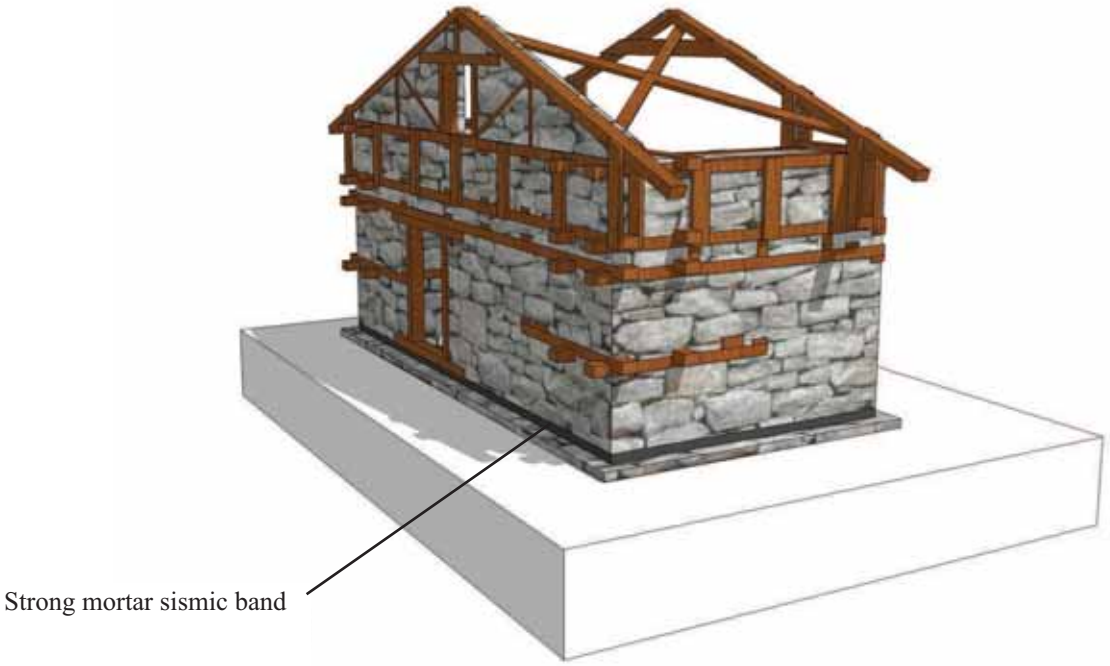
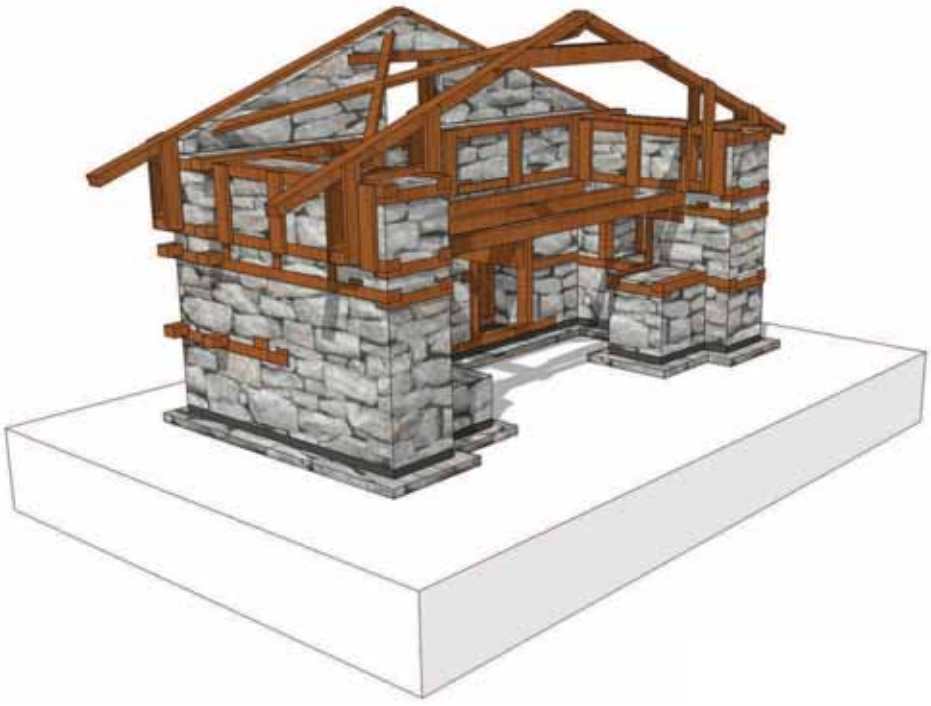
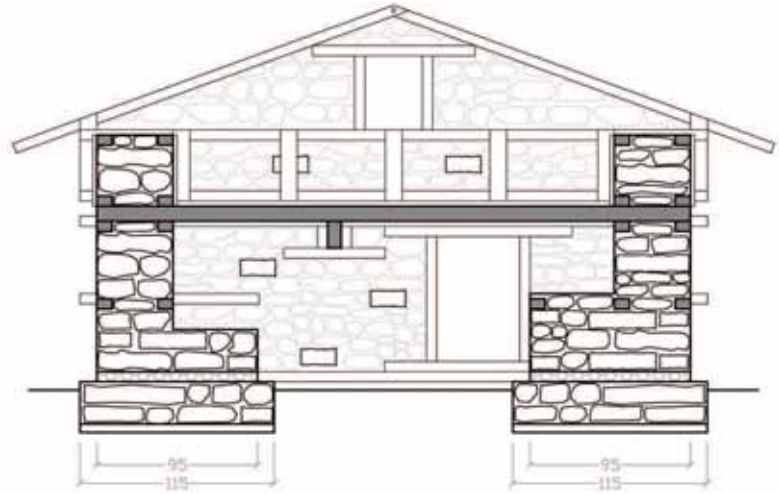
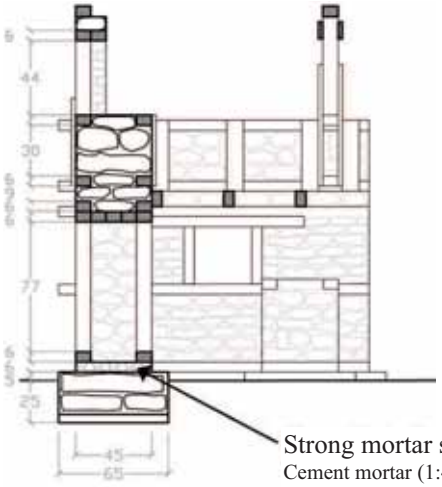
The TDW integrates technical and constructive solutions described in this guide.
It is to be built in the initial Training of Trainers (ToT) sessions, at each one of the three affected districts, with regional and contextual adjustements. The example shown on the next two pages refers to the exercise to be carried out in the first ToT, at Dolakha district.



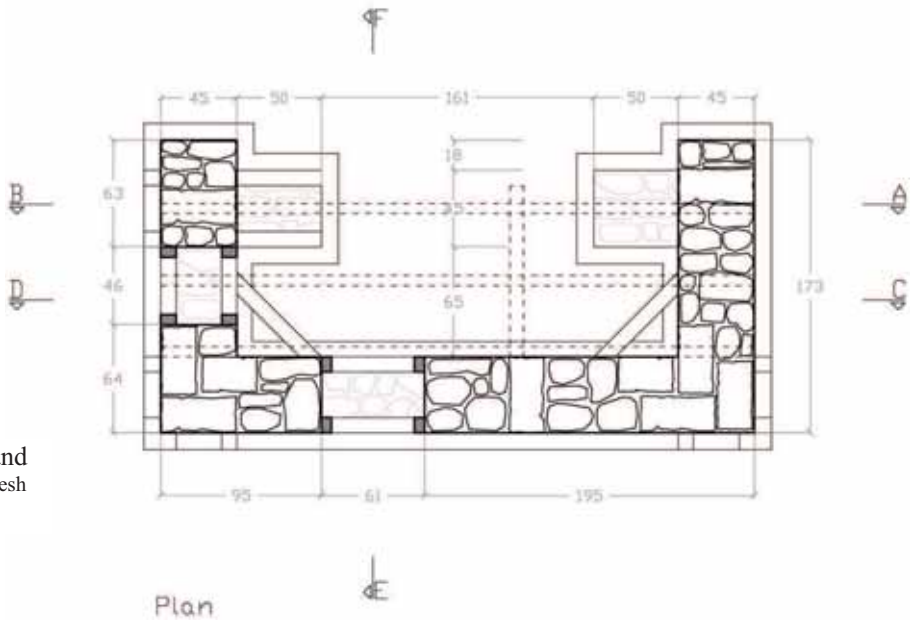




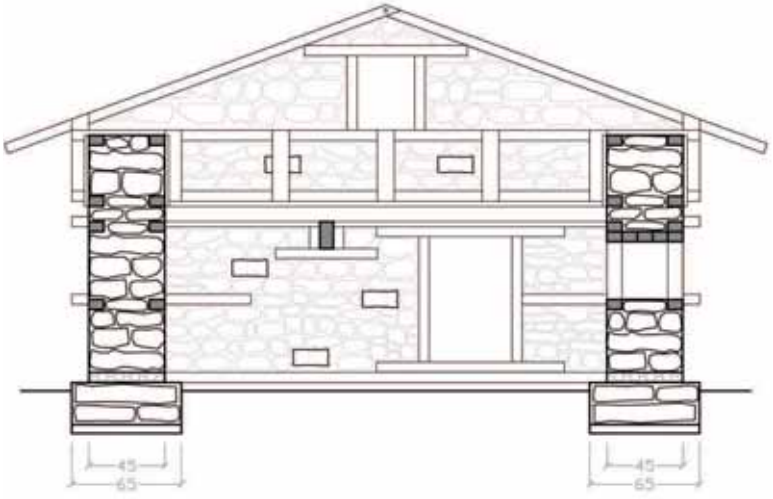
Section AB



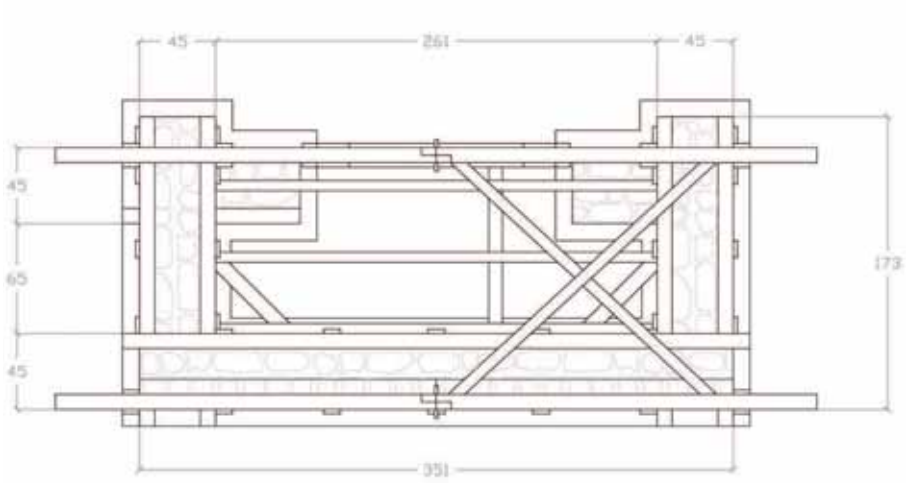
Section EF



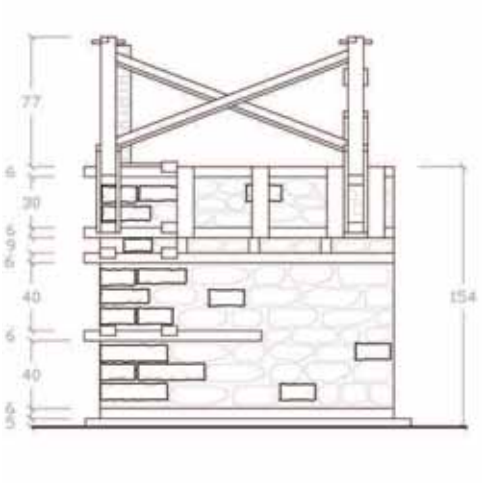
Plan



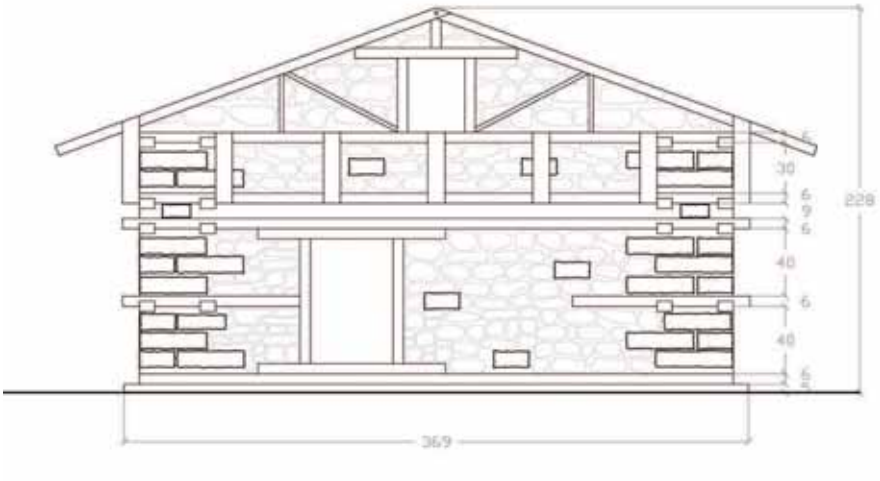
Section CD



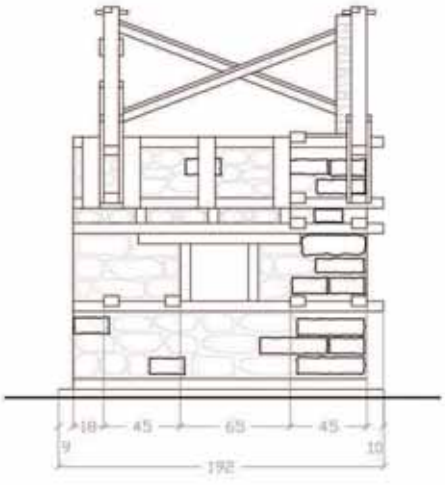
View from above



Side elevation



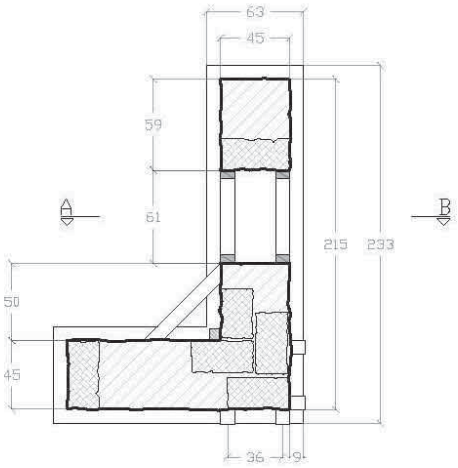
Front elevation



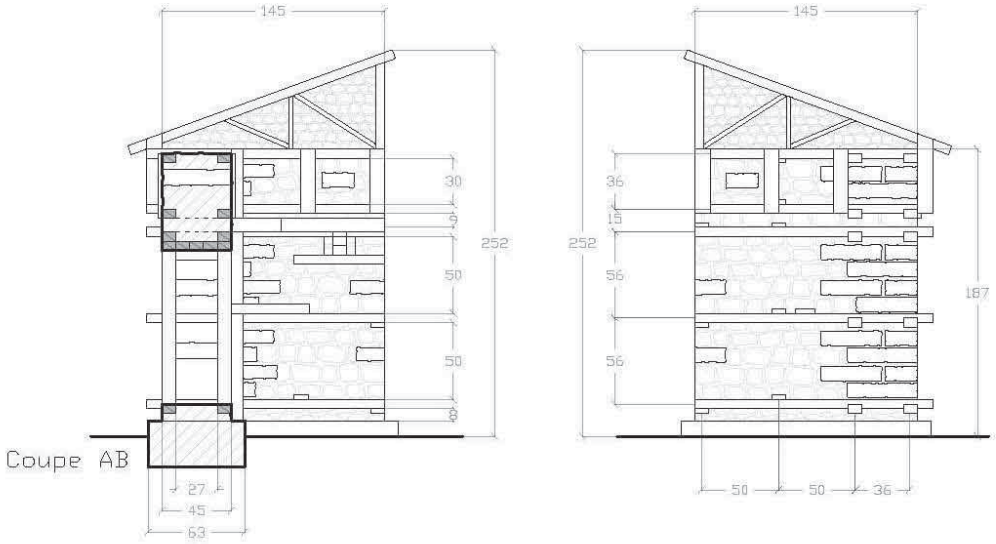
Side elevation

The TDS integrates technical and constructive solutions described in this guide.
It is meant to be built in the village level trainings, over the several VDC in the three affected districts, with regional and contextual adjustements.

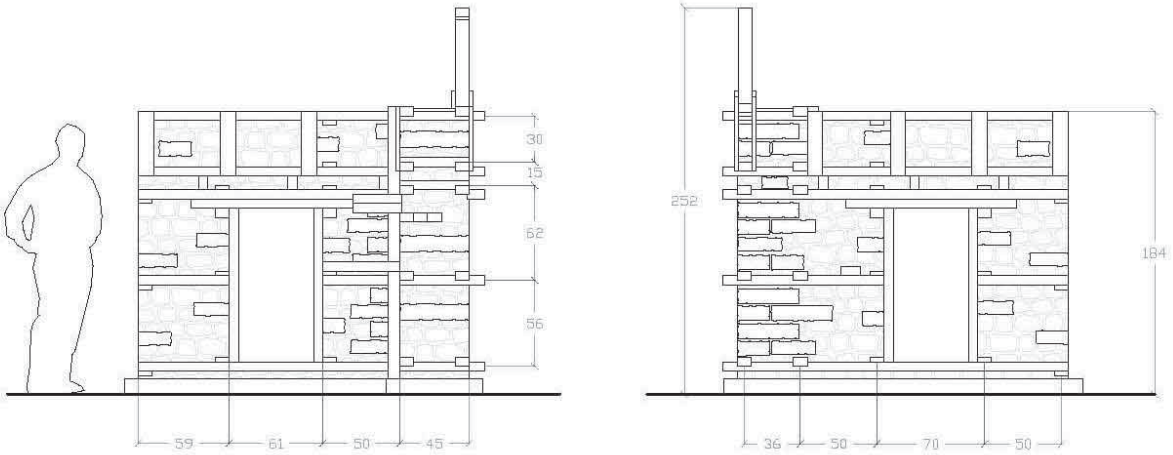
PLAN



SECTIONS



ELEVATIONS



Definition

DOT is a boron compound with many uses, amongst which anti-fungal ones. It can also be used in soft wood treatment.

The main reasons why DOT treatment is a valid choice are :

its low toxicity to humans;

its affordable price;

the fact that it is simple to use, which also allows the setting of small scale (village) units;

its efficacy against insects (namely termites) and fungi;

the fact that, additionally, it is also a fire retardant.

Nevertheless, its effectiveness depends on a thorough preparation and execution of the whole process.

Method

The treatment consists on soaking the wood pieces into a prepared boron solution for a proper impregnation.
For an easier and reliable process, a soaking tank is required.

This tank can be easily done in wood, making sure that :

- the tank's length is equal or bigger than the length of the wood pieces that are going to be soaked in it, and its depth and width allow an easy handling of the elements to soak;
- screws and not nails are used, for a better fixing, but also to allow the tank's dismantling and re-assembly.
- longitudinal reinforcement are included, since the horizontal loads are considerable, when the tank is full (eventually, this tank can be buried, wich solves this issue);

Waterproofing can be achieved with a good plastic sheeting. Since any leaks can easily become quite expensive, due to the product's price, it is highly recommended to fold the plastic twice, resulting in 4 layers, to ensure proper waterproofing. Set the plastic properly against the wood, avoiding air in between, to avoid any stress when filling the tank, that could lead to accidental plastic shearing.

All wood elements should be cut, carved and finalised before entering the treatment tank. Any further cuts would expose the resulting untreated surfaces of the wood, jeopardizing it.

Photos : Julien Hosta

Dilution

For a proper preparation of the boron solution, check the product's technical indications.

The dilution is made with water.
For an optimised use of the product and an easy procedure, it is recommended :

- calculate the volume of solution to prepare. This can be easily done knowing the tank's surface and the height of solution required for soaking the wood pieces (depending on the size of these);

- put the total volume required of water (from the previous calculations) inside the tank;

- add small quantities of salt little by little. To do this, fill half a bucket with the salts and the other half with water (collected from the tank, so that the poportion of the dilution is not changed) and dissolve it before dumping into the tank. After this, keep stirring the solution in the tank.

- once the whole amount of salts is mixed into the tank, wait for the solution to be completely homogeneous before starting to soak the wood pieces in it.

Right after the end of each soaking session, take note of the height of the solution inside the tank. Mesure it again right before starting another session. If it has decreased, it means that some water has evaporated and if so, some more water has to be added to the tank, until reaching the previous level of the solution, to make sure the proportion of the dilution is kept (since water evaporates, but not the salts).

Photos : Julien Hosta

Soaking

Put the wood pieces in the tank one at the time, being careful not to damage the plastic.

For practical reasons, it is recommended to choose wood pieces with equal size/thikness for each soaking session.

Once all the wood pieces are put inside the tank, load them with something on top, so that they stay properly immerse. (unlike in the photos!)

From that moment, count 30 minutes.

Dripping

Put some wood laths over and across the tank, and lay the wood pieces over them, after removing them from the tank, so that they might dripp back into the tank.
.Let them dripp for about half a minute and proceed to stocking.

Stocking

Lay the treated wood pieces over a flat surface, sepparated from the ground by some wood laths and slightly apart from each other. When stocking another layer, leave a 1" gap between layers as well. This can be done using laths or thick sisal rope, for example.

Diffusion

It is during this phase that the solution penetrates deep inside the wood, through osmosis.
Drying too fast can result in a bad diffusion process, which means only the surface gets treated. Therefore, the wood pieces should be wrapped in a waterproof tarpaulin right from the moment when they come out of the soaking tank.
The wood must then stay wrapped for at least 48h. It can also remain stocked like this, without any problems, until being shifted to the construction site.

Photos : Julien Hosta

Quality control

To set up a quality control, it is necessary to determine the penetration and retention of the wood preservative.
For this, some samples from the stock have to be cut at half length.

The cut ends will then be sprayed with a mix of:

-10 g of turmeric;
- 100 ml of alcohol (with over 90% cont.).

Once the sprayed wood parts become dry, apply a "revealing" solution, made with :

- 20 ml of hydrochloric acid (concentration 34%)
- 6 g of salicylic acid dissolved in 100 ml of alcohol (with over 90% cont.).

The wood parts where the preservative has penetrated become red, but those where there has not been proper diffusion remain with the wood's original color.

A good penetration would generate a red staint that would go nearly as deep in the tested wood piece as half its thikness.

The color that the "revealing" solution assumes depends on the retention of the wood-treatment product.
The colors below show various boron retention in kg/m3.

Photos : Julien Hosta

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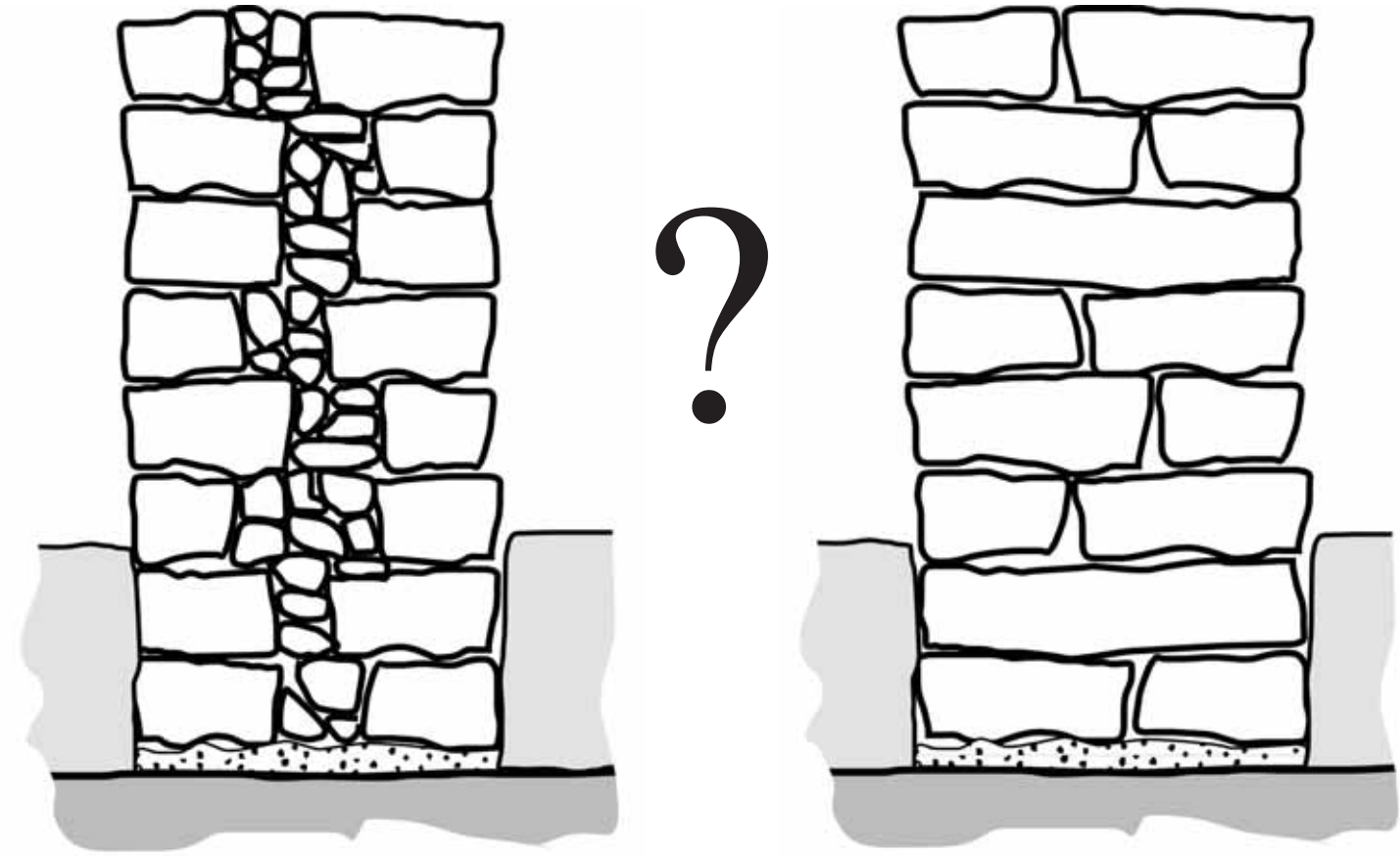
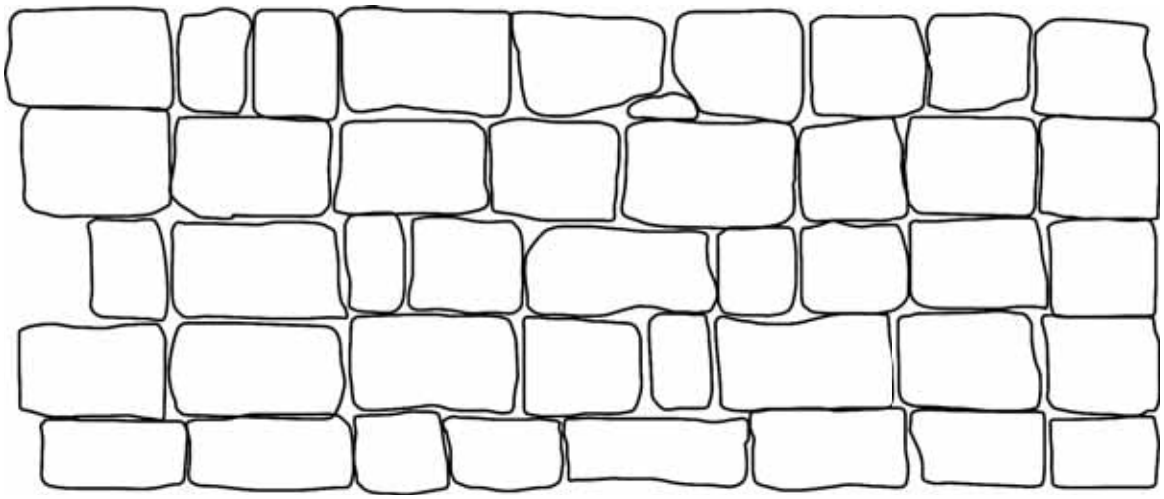
Seismic Stabilization of historic adobe structures. Final report of the Getty seismic adobe project / E Leroy Tolles, Edna E. Kimbro, Frederick A. Webster, William S. Ginell. Los Angeles: The Getty conservation institute. 2000

Which of the following walls is the most resistant ?



Stone wall: Vertical joints

Which of the following walls is the most resistant ?



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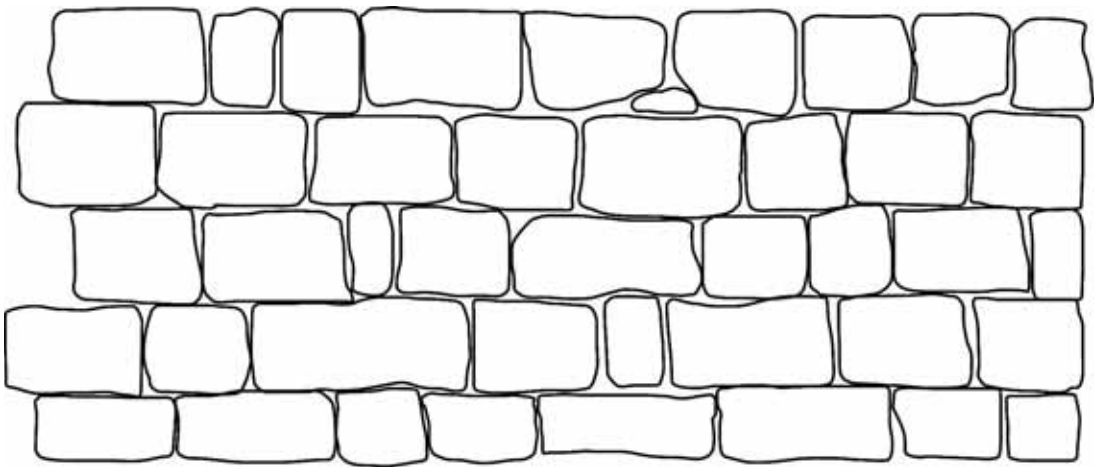
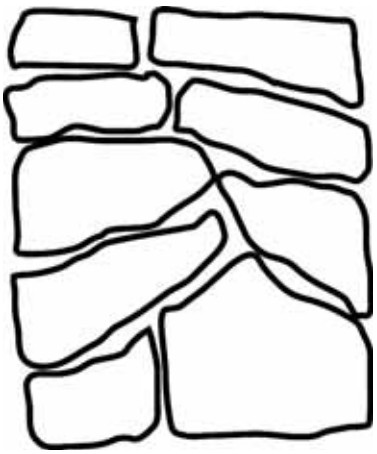


Which of the following walls is the most resistant ?



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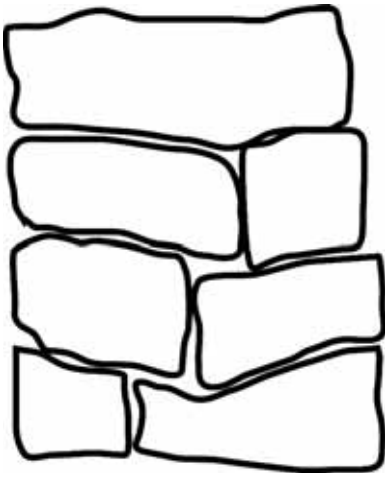
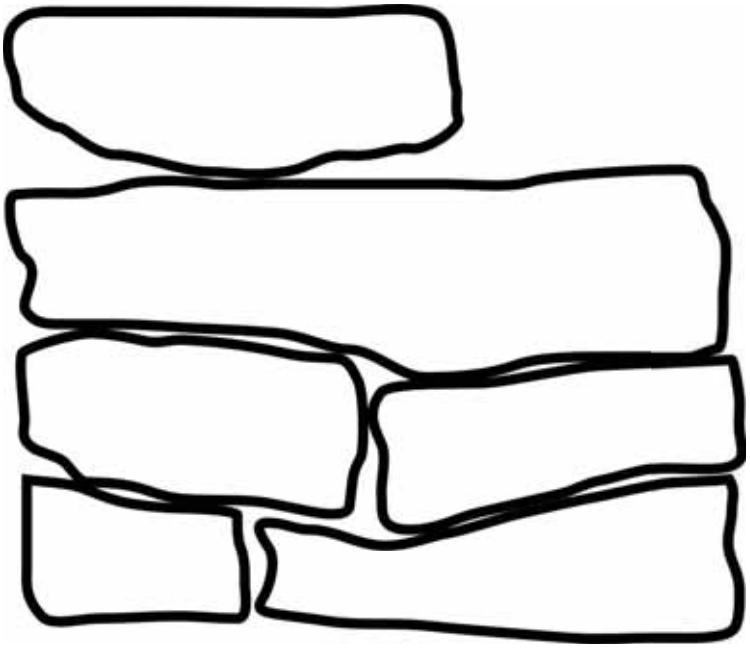
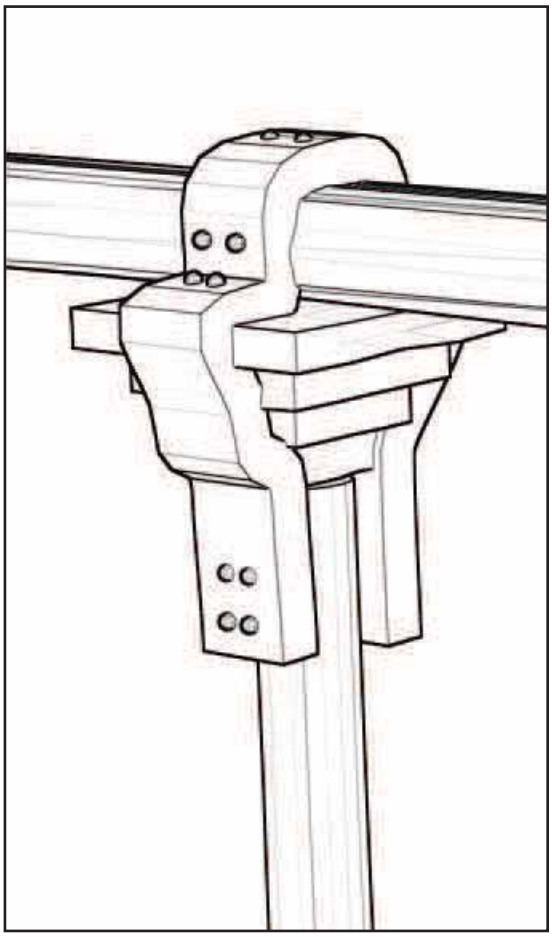


Where to put the small stone first to block the big stone ?



Which one of the following fixing system is the most adapted to eartquake prone areas ?



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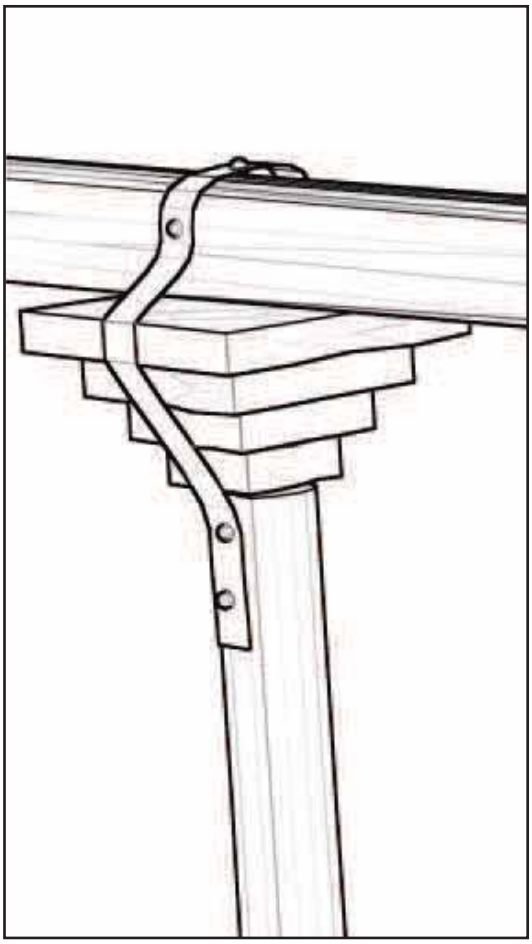
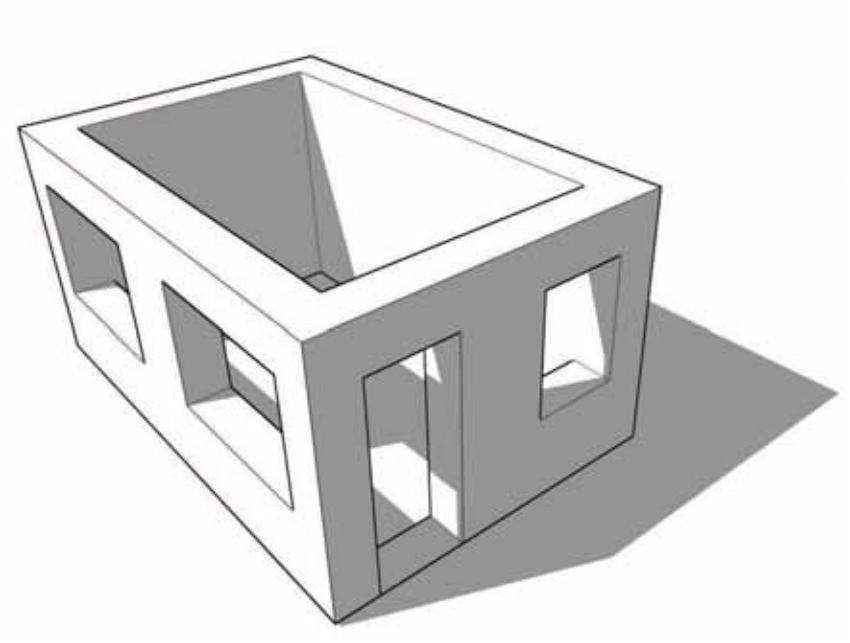


Which one of the following buildings will be the most resistant to earthquakes ?



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